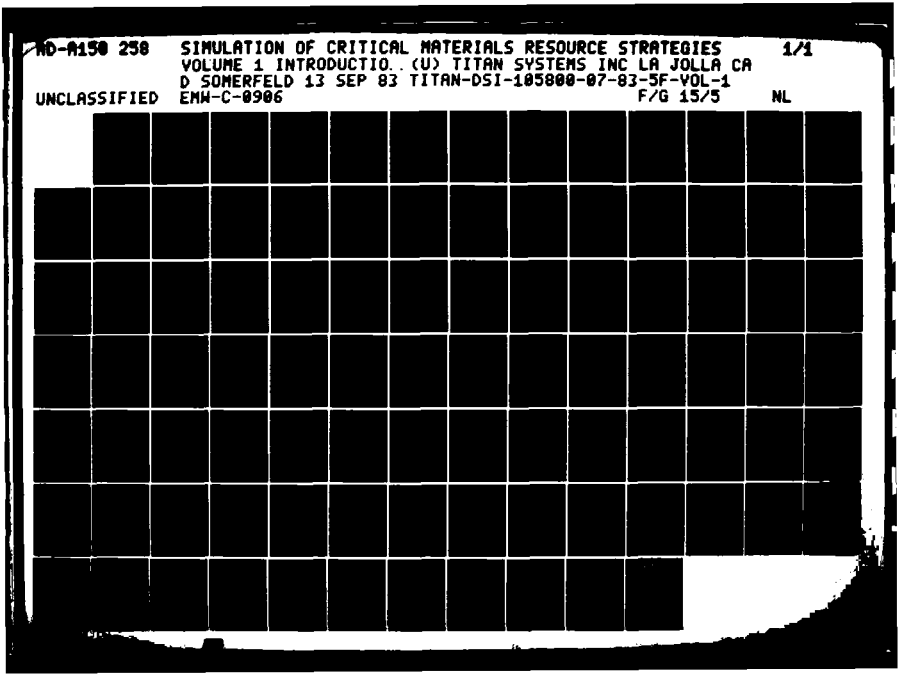
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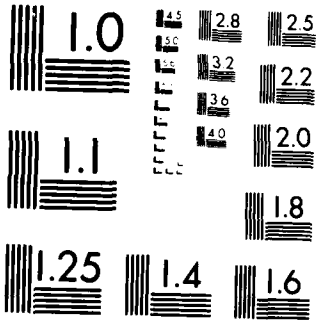

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a division of TITAN SYSTEMS, INC.

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VOLUME I

SIMULATION OF CRITICAL MATERIALS RESOURCE STRATEGIES

INTRODUCTION THROUGH APPENDIX C

AD-A150 258

FINAL REPORT

CONTRACT EMW-C-0906

ARTICLE III A

Submitted to:

Mr. Michael Pfetsch
FEMA
Program Manager
Donohoe Building, Room 617
500 "C" Street, S.W.
Washington, D.C. 20472

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TITAN SYSTEMS, INC.
9191 Towne Centre Drive
(La Jolla Gateway) Suite 500
San Diego, California 92122

(619) 453-9500
postal address: P.O. Box 12139
La Jolla, California 92037

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This report addresses preliminary efforts to quantify strategic relationships of materials to force elements.
The results of the preliminary materials are emergency but requires further model development.

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SIMULATION OF CRITICAL MATERIALS RESOURCE STRATEGIES

ABSTRACT

Objective : Examine current plans for assuring certain raw materials are available and develop an explicit representation to enable evaluation of interactive strategies. Specifically, address the worth of the force elements and their requirement for critical materials; identify vulnerability by source; compute the importance of critical materials; consider substitution; identify critical deficiencies; and structure a joint US/USSR expression of national purpose.

Background: To ensure our national security, resources must be available to continue production for maintenance of a defense capability over a protracted period of time. FEMA is charged with the responsibility of determining the stockpile requirements for strategic and critical materials in support of national policy. To asssist in the decision-making process, FEMA must have the data and capability to simulate various scenarios and acquisition strategies to supplement existing model capabilities.

Approach: Decision Science has a top-down methodology which will quantitatively relate the importance of the force elements to the critical materials; considers various levels of conflict in the context of military resources and regional importances; evaluate commodity sources; assess the effects of substitution; and portrays the national purpose of the adversary superpowers.

Specifics: The methodology was exercised to successfully show that an interrelationship between the force elements, the weapon platforms, commodity importance and the status of the stockpile could be established and analyzed under various conditions. Moreover, the vulnerability of the sources can be assessed. Several modes of material substitution were considered and the results assessed. The capability to prioritize both commodity importance and force element requirements was demonstrated. The ability to assess the impact and resource allocation requirements resulting from moves and countermoves on the part of the adversary superpowers was developed. The methodology employed is transparent, providing a ready audit trail for review of data input.

Conclusions and Recommendations: The demonstration of the Decision Science methodology has conclusively shown

the capability to relate commodities, sources, stockpile requirements, military assets and the external environment (military, political and socioeconomic) in a dynamic, interactive evaluation of strategies relative to the strategic and critical material stockpile. The definition of the Joint US/USSR Purpose enables, for the first time, a quantitative evaluation of the interactions of the superpowers. The study should be enlarged to encompass all the critical materials and their relationship to the force elements. Further, the Joint US/USSR Purpose should be definitized to a finer detail and the payoff functions defined.

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INTRODUCTION

As stated in the Strategic and Critical Material Stock Piling Act, the purpose of the stockpile is "...to decrease and preclude, when possible, a dangerous and costly dependence by the United States upon foreign sources for supplies of (strategic and critical) material in time of national emergency." Moreover, the stockpile "...should be sufficient to sustain the United States for a period of not less than three years in the event of a national emergency..."

The program of the Natural Resources Division of the Resources Preparedness Office, Federal Emergency Management Agency, is designed to support the above policy in obtaining and stockpiling certain critical materials. The plans for executing stockpiling policy are based on assumptions concerning political and military strategies. Moreover, the current resource strategies and stockpile planning factors are based on a static evaluation of political reliability and are not able to permit interactive evaluation of strategies relative to adversary major powers, regional importances or source governments. Since unsuccessful strategies,

developed during premobilization periods, could severely impact the amount of critical materials available during a national emergency, it is of paramount importance that FEMA have the analytic tools available to simulate the various strategies and thus assist in the decision process.

Decision Science, a Division of TITAN Systems, Inc., has developed a quantitative method for specific delineation of purpose and the computation of the relative worth of the alternative methods in achieving this purpose. This approach is readily applicable to the assessment of regional influences and the importance of various materials to military force elements in the execution of our national purpose. Further, a unique joint US/USSR Purpose, constructed from the specific national purposes of each of the superpowers, enables the evaluation of the interactions (moves and countermoves) of the adversaries as they affect the U.S. stockpile actions and posture.

BACKGROUND

Readiness to ensure preservation of our national security rests in a large part on having the resources available to continue production and maintenance of a defense capability over a protracted period of time. Current national policy establishes this as a three-year period and considers that the U.S. will be faced with a nonnuclear theater war. The current administration has expressed its commitment toward resource availability by initiating major additions to the stockpile. In support of the determination of stockpile requirements, FEMA has in being a methodology which is accepted at the executive and legislative levels of government, with the GAO noting it is a reasonable approach. To assist in the decision process, FEMA must have the data base and capability to simulate various scenarios and acquisition strategies to supplement existing capabilities in the determination of the degree of U.S. vulnerability and the application to strategic and critical materials.

The study purpose is to examine current plans for obtaining and stockpiling certain raw materials to assure that the production capability exists to supply required defense needs and military production. Second, an explicit

representation will be developed to enable evaluation of interactive strategies employed by adversary major powers, regional influences or host governments.

In providing the necessary data base, the top-down approach proposed by Decision Science recognizes the fact that the stockpile problem is big, has competing and often conflicting goals, and limited fiscal resources. Some of the issues may well be very subjective, particularly when considering the political ramifications. Consequently, quantification is required to improve communication, enable concise coordination of the subjective values and allow specific tradeoffs. Specifically, the Decision Science methodology: Incorporates the importance of the force elements in prioritizing our critical materials; considers discrete or aggregated levels of conflict, considering force element use and region importance; evaluates commodity sources based on the assessed degree of military significance to the U.S. over the four control domains of land, air, sea and space; enables sensitivity analyses relative to substitution, changes in sources, application of military power and changes in the political environment; and portrays in a joint state space the national purpose of the adversary major powers.

OBJECTIVES

The following tasks were to be performed in meeting the contractual requirements:

Task I - Define national purpose; particularize it to the military force elements and the relative worth of each.

- Infer each force element's requirement for critical materials.

Task II - Survey material requirements; identify vulnerability by source.

- Consider possible military, social and economic threats.

Task III - Compute the importance of the most critical materials based on the need for each.

Task IV - Consider substitution and the degree to which a material deficiency can be tolerated.

Task V - Identify critical deficiencies by comparing incoming material resources and the stockpile reserve with the projected requirement.

Task VI - Structure the US/USSR purpose into a joint state space.

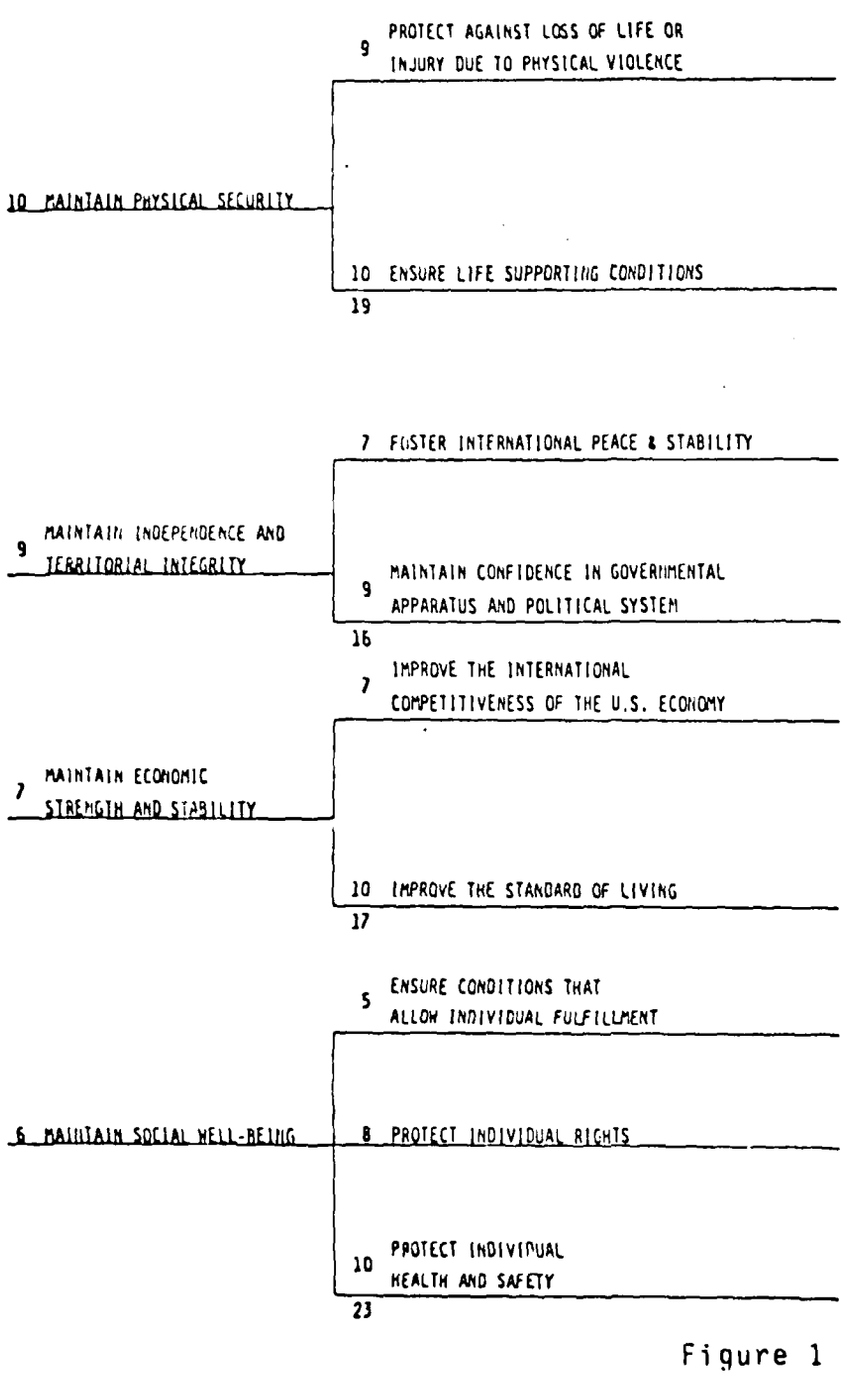
- Calculate worth of alternative moves.

METHODS

Adopting a top-down approach as incorporated in Decision Science methodology requires that we begin with our national purpose, particularize this to the force elements (and related weapon systems) and then to the related materials that would require stockpiling to ensure there is no exploitable vulnerability in our ability to defend and further our national interests. This will translate to a prioritized list of materials relative to the force elements and then to a prioritized list of sources by commodity so that we can meaningfully examine the supply and reservoir of these in descending order of importance.

The first step is to determine the worth of the force elements as specified in Task I. Our statement of U.S. national purpose was reviewed and updated to reflect the current administration (Figure 1). The level of achievement of national purpose for each level of conflict was computed (Figure 2). A total of 30 generic force elements has been identified as an outgrowth of previous studies and consultations with ODS/Net Assessment (see Appendix A). For each military control domain (i.e., land, air, sea and space) and the appropriate geographical and spatial regimes, deterrence and warfighting values have been assigned (see Progress Report No. 2, Appendix B, dated

Figure 1



	PEACE	CRISIS	NON-NUCLEAR	NUCLEAR	INITIAL	TRANSITION	RECOVERY RESET
10 DETER ATTACK AGAINST U.S. OR PREVAIL IN WAR	10	10	10	10	5	0	0
8 DETER ATTACK AGAINST FORCES O'SEAS OR PREVAIL	10	10	0	0	0	0	0
7 DETER ATTACK AGNST ALLIES OR PREVAIL IN WAR	10	10	0	0	0	0	0
7 PROTECT AGNST INTIMIDATION OR THREAT OF VIOLENCE	7	5	0	0	0	0	0
5 PROTECT ALLIES AGNST INTIMIDATION OR NUCLR BK-MAIL	7	5	5	0	0	0	0
3 PROTECT 3RD-WORLD COUNTRIES FROM COERCION	5	3	1	1	0	0	0
3 PROTECT U.S. NATIONALS OVERSEAS	5	5	1	1	0	0	0
5 ENCOURAGE COL SECURITY MEASURES WITH ALLIES	7	7	7	5	5	0	0
7 PROTECT AGNST RIOTS & INSURRECTION	7	7	5	3	1	0	0
55							
10 ENSURE AVAILABILITY OF FOOD AND WATER	10	10	8	5	3	0	0
8 ENSURE AVAILABILITY OF SPACE AND HOUSING	8	8	5	3	2	0	0
5 PROVIDE PROTECTION AGNST DISEASE	8	8	5	3	2	0	0
3 PROVIDE PROTECTION & RELIEF FROM NATURAL DISASTER	8	8	5	3	2	0	0
1 PROTECT THE NATURAL ENVIRONMENT	6	6	3	1	0	0	0
29							
9 MAINTAIN & STRENGTHEN COLLECTIVE SECURITY	8	8	8	8	8	0	0
5 ENCOURAGE & ASSIST 3RD-WORLD	5	5	2	1	1	0	0
3 SUPPORT & ENCOURAGE INTERNATIONAL ORG - LAW	7	7	2	2	1	0	1
6 PROMOTE DEMOCRATIC IDEOLOGY & HUMAN RIGHTS	8	8	4	4	2	0	1
10 INHIBIT SPREAD OF HOSTILE IDEOLOGIES & INFLUENCE	3	3	3	3	3	0	1
33							
10 ENSURE EQUITABLE SYSTEM OF LAW & JUSTICE	10	10	5	5	2	0	0
7 ENCOURAGE BROAD PARTICIPATION IN GOVERNMENT	7	7	7	5	3	0	1
6 PROVIDE EQUAL & UNIVSL. OPPORTUNITY FOR IND. ADV.	8	8	5	5	2	0	0
8 MAINTAIN CONFIDENCE IN ELECTED LEADERS	7	8	8	8	4	0	1
31							
6 IMPROVE PRODUCTIVITY GROWTH	6	5	3	2	1	0	1
10 MAINTAIN ACCESS & ENSURE ADEQUATE RAW MATERIALS	10	8	5	3	1	0	0
7 IMPROVE EFFICIENCY OF ENERGY USE	6	6	4	2	2	0	1
9 MAINTAIN SUPERIOR TECHNOLOGICAL BASE	10	10	10	10	5	0	1
4 IMPROVE THE BALANCE OF PAYMENTS	5	4	3	3	1	0	0
2 IMPROVE STABILITY OF U.S. CURRENCY	6	5	3	3	1	0	0
38							
10 CONTROL INFLATION	4	3	2	1	1	0	0
8 ENSURE HIGH RATE OF EMPLOYMENT	6	7	7	7	4	0	1
9 ENSURE ADEQUATE DISTRIBUTION OF GOODS & SERVICES	10	10	5	5	2	0	0
6 ENSURE AVAILBT OF DISCRETIONARY FUNDS AT ALL LEVELS	7	7	5	5	2	0	0
33							
10 ENSURE LITERACY & BASIC EDUCATION OF ALL CITIZENS	8	8	6	5	2	0	0
7 PROVIDE UNIVRSL OPPORTUNITY FOR HIGHER ED./TRAING	7	6	4	4	2	0	0
5 PROVIDE OPPORTUNITY & ENCOURAGE INDV. CULTURAL ADV.	8	7	5	3	2	0	0
3 PROVIDE ADEQUATE RECREATIONAL FACILITIES	10	9	5	4	2	0	0
6 ENSURE FREEDOM TO TRAVEL, BOTH DOMESTIC & FOREIGN	10	8	3	2	1	0	1
1 IMPROVE MORALE, AMERICAN SELF-IMAGE & IMAGE O'SEAS	6	7	7	7	4	0	1
32							
7 PROTECT INDIVIDUAL & FAMILY PRIVACY	10	9	5	3	3	0	0
9 ENSURE UNIVERSAL ACCESS TO & TREATMENT UNDER LAW	9	9	7	7	3	0	1
10 ENSURE FREEDOM OF BELIEF, SPEECH AND PRESS	10	10	7	6	3	0	1
6 ENSURE FREEDOM TO PARTICIPATE IN SOCIETIES	10	9	7	6	3	0	0
3 ENCOURAGE INTERN'L RECOG & OBSERV. OF HUMAN RIGHTS	6	5	3	1	1	0	0
35							
9 IMPROVE HEALTH CARE & INDIV. PHYSICAL FITNESS	8	8	6	4	2	0	0
7 MONITOR NUTRITION & LIMIT HEALTH ABUSE	7	7	6	4	2	0	0
5 PROTECT THE WORKER AND CONSUMER	10	9	5	5	2	0	0
8 PROVIDE PROTECTION AGNST CRIME & TERRORISM	7	7	6	4	2	0	0
4 PROTECT THE NATURAL ENVIRONMENT (QUALITY)	8	7	5	3	1	0	0
6 PROTECT CERTAIN MINORITIES (POOR, AGED, INFIRM, VETS	8	8	6	3	1	0	0
34							

Figure 1

Figure 2

CONFLICT LEVEL QUANTIFICATION

	PEACE	CRISIS	THEATER		STRATEGIC NUCLEAR		RCVY/RCNST
			NON-NUC	NUCL	LIMITED	GENERAL	
ACHIEVEMENT OF NATIONAL PURPOSE	78.19	76.25	53.17	42.30	22.99	0.0	2.82
AVERAGE DECREMENT IN NATIONAL PURPOSE (Benefit in Peace) δ_i	5.0	1.94	25.02	35.89	55.20	78.19	75.37
AVERAGE RECOVERY TIME* t_i		0.1	1.5	4.0	50.0	50.0	50.0
AVERAGE COST CONSEQUENCE C_i	5.0	0.194	37.53	143.56	2760	3909.5	3768.5
PROBABILITY P_i	1.0	0.99	0.30	0.15	0.01	0.01	0.001
AVERAGE NUMBER OF OCCURRENCES λ_i		4.605	0.357	0.163	0.010	0.010	0.001
RELATIVE IMPORTANCE $C_i\lambda_i$		0.893	13.386	23.331	27.738	39.290	3.7723

* IN UNITS OF FIVE YEARS.

Figure 2

November 19, 1982). The importances of the force elements are then calculated by straightforward application of arithmetic mean techniques in the Decision Science methodology. The values are then normalized and the prioritized list is as shown at Figure 3.[1] The value calculated for each of the force elements is independent of the critical commodities. It is a function only of level of conflict, geographical assignment, the deterrence and war fighting values related to that assignment and the importance ascribed to that geographical location as an expression of U.S. policy.

A necessary part of Tasks I and III is the relationship of the critical materials to the force elements and the determination of the importance of the critical material. For this demonstration of method, only five materials were selected for analysis from the August 31, 1982 Inventory of Stockpile Material, considered in their relationship to the force elements, their sources of supply and their strategic and critical nature. The five materials are: Cobalt (in short supply, with additional on order); tin (an overstocked commodity); fluorspar acid (in short

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[1] It should be noted here that only the level of conflict pertaining to the nonnuclear theater war (i.e., LOC 3) is considered in the calculations, although the model can determine values for any individual or aggregated levels of conflict. Second, the scope of the analysis has been deliberately limited to the defense sector for this demonstration and does not address the essential civilian and basic industrial aspects.

FORCE ELEMENT IMPORTANCE
(LOC 3)

RANKING	ELEMENT NUMBER	FORCE ELEMENT NAME	CALCULATED VALUE	NORMALIZED VALUE
1	17	CARRIER BATTLE GROUP	0.141	10.000
2	1	AIR INTERDICTION	0.117	8.264
3	3	ARMY GROUND	0.104	7.382
4	16	ATTACK SUBS	0.072	5.135
5	19	SURFACE COMBATANTS	0.060	4.249
6	12	THEATER NUCLEAR WEAPON	0.054	3.812
7	8	RAPID DEPLOY	0.052	3.706
8	6	CAS	0.044	3.132
9	14	ASW(LAND BASED)	0.043	3.083
10	22	AIR SUPERIORITY(LAND BASED)	0.041	2.910
11	15	ASW(SEA BASED)	0.033	2.315
12	23	AIR SUPERIORITY(SHIP BASED)	0.032	2.272
13	21	AIR DEFENSE(SHIP BASED)	0.029	2.065
14	10	STRATEGIC BOMBER	0.025	1.794
15	25	SPCE BASED WEAPON(AIR CNTRL)	0.020	1.416
16	29	ASAT(SPACE BASED)	0.013	0.924
17	18	MINE WARFARE	0.013	0.891
18	2	AMPHIBIOUS ASSAULT	0.011	0.757
19	13	SPECIAL OPERATIONS	0.010	0.725
20	28	ASAT(LAND BASED)	0.007	0.510
21	20	AIR DEFENSE(LAND BASED)	0.004	0.278
22	9	SPCE-BASED WEAPON(LND CNTRL)	0.003	0.212
23	30	SPCE BASED WEAPON(SEA CNTRL)	0.002	0.118
24	27	AIM(SPACE BASED)	0.000	0.000
25	26	ASM(LAND BASED)	0.000	0.000
26	24	INTERCEPTOR AIRCRAFT	0.000	0.000
27	11	SLBM	0.000	0.000
28	7	ICBM	0.000	0.000
29	5	CIVIL DEFENSE	0.000	0.000
30	4	CEW	0.000	0.000

FIGURE 3.

supply and below the cognitive level of defense users); nickel (very short supply); and pyrethrum (none available in the stockpile). Further, these five reflect a broad range of application and geographical location. The relationship of the commodities to the force elements was established by the Decision Science analyst in consultation with FEMA commodity managers. At this point, cost and schedule considerations required that detailed analysis be performed on only a limited number of force elements. Thus, for 26 of the force elements, the importance of a critical material is ascribed the value of the force element itself. However, for four force elements (Close Air Support, Air Interdiction, Antisubmarine Warfare (sea) and Army Ground) a refined methodology was demonstrated for determination of commodity importance and a more detailed assessment of relative weapon system importance. The calculation of the importance of these force elements and the commodities is as shown in Appendix B. The commodity importance and the commodity normalized importance are shown in Figure 4. It should be noted here that only force elements to which a commodity is a major contributor are considered. However, with the refined methodology demonstrated for the four force elements, the commodities can be considered in their individual contribution to the force elements and need not be treated as all "equal."

TIN BASELINE	
AIR INTERDICTION	5.90
ARMY GROUND	1.92
CAS	1.91
STRATEGIC BOMBER	1.79
ASW(LAND BASED)	3.08
ASW(SEA BASED)	1.11
ATTACK SUBS	5.13
CARRIER BATTLE GROUP	10.00
MINE WARFARE	0.89
SURFACE COMBATANTS	4.25
AIR SUPERIORITY(LAND BASED)	2.91
AIR SUPERIORITY(SHIP BASED)	2.28
INTERCEPTOR AIRCRAFT	0.00
ABM(LAND BASED)	0.00
	41.18

COBALT BASELINE	
AIR INTERDICTION	5.71
ARMY GROUND	4.52
CAS	1.75
ICBM	0.00
STRATEGIC BOMBER	1.79
SLBM	0.00
ASW(SEA BASED)	1.27
CARRIER BATTLE GROUP	10.00
SURFACE COMBATANTS	4.25
AIR SUPERIORITY(LAND BASED)	2.91
AIR SUPERIORITY(SHIP BASED)	2.28
INTERCEPTOR AIRCRAFT	0.00
ASAT(LAND BASED)	0.51
	34.99

NICKEL BASELINE	
AIR INTERDICTION	5.60
ARMY GROUND	4.92
CAS	1.75
STRATEGIC BOMBER	1.79
ASW(SEA BASED)	1.71
ATTACK SUBS	5.13
CARRIER BATTLE GROUP	10.00
MINE WARFARE	0.89
SURFACE COMBATANTS	4.25
AIR SUPERIORITY(LAND BASED)	2.91
AIR SUPERIORITY(SHIP BASED)	2.28
INTERCEPTOR AIRCRAFT	0.00
	41.21

PYRETHRUM BASELINE	
ARMY GROUND	2.68
CIVIL DEFENSE	0.00
ASW(SEA BASED)	0.14
CARRIER BATTLE GROUP	10.00
SURFACE COMBATANTS	4.25
	17.08

FLUORSPAR ACID BASELINE	
AIR INTERDICTION	7.15
AMPHIBIOUS ASSAULT	0.76
ARMY GROUND	3.46
CAS	2.05
ICBM	0.00
STRATEGIC BOMBER	1.79
SLBM	0.00
ASW(LAND BASED)	3.08
ASW(SEA BASED)	1.43
CARRIER BATTLE GROUP	10.00
SURFACE COMBATANTS	4.25
AIR SUPERIORITY(LAND BASED)	2.91
AIR SUPERIORITY(SHIP BASED)	2.28
INTERCEPTOR AIRCRAFT	0.00
ABM(LAND BASED)	0.00
	39.57

COMMODITY NORMALIZED IMPORTANCE		
NICKEL	10.00	(41.21)
TIN	9.95	(41.18)
FLUORSPAR ACID	9.60	(39.57)
COBALT	8.49	(34.99)
PYRETHRUM	4.14	(17.08)

FIGURE 4.

COMMODITY IMPORTANCE
(LOC 3)

The purpose of the stockpile is to support the forces in the event of a war, and thus the stockpile must be relatable to the force elements. This is achieved in the context of the force element/commodity importance already derived and using the commodity shortfall, expressed as a percentage, as an input measure of merit. For this analysis, all values are translated to delete tin as a commodity of concern, since it is overstocked. In follow-on analyses, overstocked commodities would not be studied; this, however, has no affect on the applicability of the methodology. The normalized product of the force element/commodity importance and the shortfall provides the criticality index, which demonstrates that materials can in fact be prioritized through their relationship to the force elements (Figure 5). The methodology has now provided results for Tasks I and III, using the inventory as a point-in-time value. As with other elements of this demonstration, inventory values would be entries in the appropriate time frame for expanded analysis.

Task II requires the assessment of source vulnerability as related to requirements and military, socioeconomic and polictical conditions. The relational aspects are a function of the commodity sources and the "external" influences (i.e., military, political, etc.). Each source can be identified with required military control of certain regions (because the source country is in that region and because certain

CRITICALITY OF SHORTFALL
ALL FE'S
(LOC 3)

COMMODITY	GOAL (UNITS)	STOCK PILE (UNITS)	SHORT FALL (%)	TRANS-LATED	FE/ CMODITY IMPORT.	CRITIC-ALITY	NORMALIZED FE/ CRITICALITY
COBALT	85.4	43.8	-48.7	402.5	8.5	3418.1	7.8
TIN	42.0	190.6	353.8	0.0	10.0	0.0	0.0
NICKEL	200.0	32.2	-83.9	437.7	10.0	4377.1	10.0
FLUORSPAR ACID	1400.0	895.0	-36.1	389.9	9.6	3744.3	8.6
PYRETHRUM	500.0	0.0	-100.0	453.8	4.1	1880.7	4.3

FIGURE 5.

other regions must be transversed if the material is to reach our country). The four media, land, air, sea and space and the regional associations are shown in Appendix C. Also shown are the source, media, regional structures. For example, Finland is in LAND-EUROPE; with AIR-NORTH ATLANTIC as well as SEA-NORTH ATLANTIC considered for transport of cobalt.

Using the Decision Science methodology, each of the regions is attributed a relative importance to our national well being, as part of our national purpose pertinent to measuring our national security through military control of land, sea, air and space by region as well as conflict. Figure 6(a) shows the importance assigned by media and region. For example, Media 1, Region 6 (Land Control-Third World) has an ascribed importance of 2.0, as compared to Media 1, Region 2 (Land Control-Europe/Mediterranean) which has an importance of 10.0. This is an indicator of where assets would probably be applied (either financial or physical) to achieve and maintain military control. However, because of the multiple regions which may influence the source of any given commodity, the regional importances must be established across all the regions and media to compare the value of control. Figure 6(b) shows the importance value of controlling any region to that of controlling any region of any other media. The term "I/COEFF" stands for influence coefficient and represents the calculated military significance ascribed to any particular area, as

WEIGHTS on REGION by LEVEL of CONFLICT and MEDIA

Level of Conflict 2 Media 1

Region	1	2	3	4	5	6	7	8	9	10
Weight	10.0	10.0	7.0	5.0	7.0	2.0	2.0	5.0	2.0	5.0
I/COEF	0.1786	0.1786	0.1250	0.0893	0.1250	0.0357	0.0357	0.0893	0.0357	0.1071

Level of Conflict 2 Media 2

Region	1	2	3	4	5	6	7	8	9	10
Region	11									
Weight	10.0	10.0	9.0	4.0	7.0	5.0	1.0	8.0	7.0	5.0
Weight	9.0									
I/COEF	0.1333	0.1333	0.1200	0.0533	0.0933	0.0667	0.0133	0.1067	0.0933	0.0667
I/COEF	0.1200									

Level of Conflict 3 Media 3

Region	1	2	3	4	5	6	7
Weight	10.0	10.0	10.0	8.0	6.0	4.0	8.0
I/COEF	0.1786	0.1786	0.1786	0.1429	0.1071	0.0714	0.1429

Level of Conflict 3 Media 4

Region	1	2	3	4
Weight	10.0	4.0	2.0	1.0
I/COEF	0.5882	0.2353	0.1176	0.0588

FIGURE 6(a)

Importance of controlling ANY Region
within its Media as compared to the Importance
of controlling ANY Region of any other Media

Media 1

Region	1	2	3	4	5	6	7	8	9	10
I/COEF	0.0099	0.0099	0.0070	0.0050	0.0070	0.0020	0.0020	0.0050	0.0020	0.0050

Media 2

Region	1	2	3	4	5	6	7	8	9	10
Media 11										
Region										
I/COEF	0.0037	0.0037	0.0033	0.0015	0.0026	0.0019	0.0004	0.0030	0.0026	0.0019
I/COEF	0.0033									

Media 3

Region	1	2	3	4	5	6	7
I/COEF	0.0060	0.0060	0.0060	0.0048	0.0036	0.0024	0.0048

Media 4

Region	1	2	3	4
I/COEF	0.0065	0.0026	0.0013	0.0007

FIGURE 6(b)

contained in the Decision Science data base. Correlation of these influence coefficients with Appendix C show that Finland has values of LAND-EUROPE = .99, and AIR- and SEA-NORTH ATLANTIC = .33 and .60 respectively. This compares to Zaire values of LAND-THIRD WORLD = .20, AIR-THIRD WORLD = .04 and SEA-SOUTH ATLANTIC = .48. Since these regions are mutually exclusive, the composite importance can be found by adding the individual factors. Thus a normative view indicates that the composite importance for Finland as a source of material is 1.92 while that of Zaire is .72. It can be noted that the Third World and contiguous waters usually score low. As will be observed in this analysis, many commodity sources are in fact in these areas.

We are not in a position to measure our actual degree of control by region. It is reasonable to expect that the more important the region, the more likely it is to have military resources applied to a region. Although we attempt to allocate military resources according to the need, it seems reasonable to assume that there is some deficiency and that the amount of that deficiency of control is greater for militarily lesser important regions; that is, it is inversely proportional to the composite importance of the regions. Thus, as an alternative to measure control directly, it seems reasonable to accept inverse composite importance as a measure of the lack of control (more specifically, an indication of

our inability to assign resources to that composite region).* The composite importances for the LOC 3 baseline are as shown in Figure 7.

The region importances, a representation of the military control by region through allocation of resources, will reflect the vulnerability to military aspects directly and to the political and socioeconomic questions inferentially. Any changes in the allocation of resources will change the relative importances of the source countries and thus reshape our thinking as to where national attention should be directed. As an example, assume a major national concern is the acquisition of cobalt. Without consideration of amounts, it can be observed from Figure 7 that the African countries, which are cobalt sources, generally rank low in military importance as reflected by the higher inverse composite importance. However, the criticality of this can only be measured in terms of the relative amount of material provided by this source. The amount of attention required on a source country is the product of the percent of the material coming from that country times the inverse composite importance factor (see Figure 7). The final step is the relationship of source/commodity importance to the force element/shortfall criticality

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* With the understanding that there is some minor "double counting" because that importance also reflects the worth of critical materials and the protection of stockpiles in calculating force element worth.

COMPOSITE IMPORTANCE
(LOC 3)

COBALT

URCE	AMOUNT SUPPLIED	% OF TOTAL	COMPOSITE IMPORTANCE	1/CI	%(1/CI
INLAND	1350.	6.43	1.92	0.520	3.343
ROCCO	450.	2.14	1.50	0.667	1.429
TSWANNA	250.	1.19	0.71	1.404	1.671
UTH AFRICA	150.	0.71	1.19	0.841	0.601
IRE	12500	59.52	0.71	1.404	83.548
MBIA	3500.	16.67	0.71	1.404	23.399
ILIPPINES	50.	0.24	0.92	1.087	0.259
STRALIA	400	1.90	0.92	1.087	2.070
W CALEDONIA	250.	1.19	0.92	1.087	1.293
NADA	1100.	5.24	2.89	0.346	1.813
S	1000.	4.76	2.56	0.391	1.863
TOTAL:	21000.	100.00			

FIGURE 7.

This is straightforward multiplication and normalization (i.e., %(1/CI) X FE/Shortfall Criticality). The source importance by commodity is thus established and can be ranked. The baseline relative importances are the values shown in Figure 8. Using this technique, change in regional importances will result in shifts in relative importance, reflecting where national attention should be placed. Since the assigned regional importances can reflect a range of national policies, the methodology will reflect changes in application of military resources, financial aspects or political conditions. Thus, the requirements of Task II can be achieved.

The requirements of Task IV, which address the impact of substitution and the degree of toleration of material deficiency, are met through application of the model. In the scenarios analyzed (see Appendix D), changes in amount by source, development of new sources, changes in stockpile requirements and changes in force element requirements were considered. Material deficiencies are readily apparent in commodity importance calculations, to be discussed in the next section of this report.

For Task V, consideration of incoming material and the stockpile reserve is a function of the composite importance at a given level of conflict based on the degree of importance of a region and the implied allocation of military resources. Using cobalt as an example, the inverse composite importances

SOURCE IMPORTANCE
RANKED BY SOURCE
(LOC 3)

SOURCE	COMMODITY	VALUE
ZAIRE	COBALT	100.00
KENYA	PYRETHRUM	37.44
TANZANIA	PYRETHRUM	36.51
ZAMBIA	COBALT	28.00
CANADA	NICKEL	26.14
SOUTH AFRICA	FLUORSPAR ACID	24.65
MEXICO	FLUORSPAR ACID	22.30
U S	NICKEL	17.34
AUSTRALIA	NICKEL	13.68
RWANDA	PYRETHRUM	11.70
SPAIN	FLUORSPAR ACID	8.31
EAST AFRICA	FLUORSPAR ACID	5.72
ITALY	FLUORSPAR ACID	5.40
DOM REPUB	NICKEL	4.95
U S	FLUORSPAR ACID	4.46
FINLAND	COBALT	4.00
INDONESIA	NICKEL	2.74
PHILIPPINES	NICKEL	2.74
USSR	NICKEL	2.67
THAILAND	FLUORSPAR ACID	2.65
AUSTRALIA	COBALT	2.48
U S	COBALT	2.28
CANADA	COBALT	2.17
SOUTH AFRICA	NICKEL	2.12
BOTSWANNA	COBALT	2.00
UK	PYRETHRUM	1.87
MOROCCO	COBALT	1.71
NEW CALEDONIA	COBALT	1.59
GUATAMALA	NICKEL	1.32
SOUTH AFRICA	COBALT	0.72
SOUTH AFRICA	PYRETHRUM	0.56
AUSTRALIA	PYRETHRUM	0.54
PHILIPPINES	COBALT	0.31
FINLAND	NICKEL	0.24
GREECE	NICKEL	0.15
YUGOSLAVIA	NICKEL	0.13
NETHERLANDS	NICKEL	0.05
FRG	NICKEL	0.03
MALAYSIA	TIN	0.00
PRC	TIN	0.00
BRAZIL	TIN	0.00
BOLIVIA	TIN	0.00
UK	TIN	0.00
INDONESIA	TIN	0.00
THAILAND	TIN	0.00
U S	TIN	0.00
AUSTRALIA	TIN	0.00

FIGURE 8.

are as stated in Figure 7. Again, the larger the number, the less the military importance inferred. As a reasonable first step, if the inverse composite importance is expressed as an equation

$$1 - \frac{\text{Normalized Inverse Composite Importance}}{100}$$

it will represent the degree of assurance that the commodity can be safely transported to the United States for use in sustaining the national purpose. However, this is meaningful only if it is associated with the material potentially supplied. The results are as shown in Figure 9. It can be noted that this is a more conservative result than presented in FEMA documentation and reflects the view that control of land, sea and air even in the U.S. and Canada may not be complete enough to ensure the safe shipment of all available cobalt.

Turning to Scenario 7, which reflects a change in media importances for only Zaire, the resultant enhancement in material potentially supplied is as shown in Figure 10. This is a considerably more optimistic view than presented in the FEMA documentation, resulting from the assumption that sufficient military resources are available to support this change in source importance. The answer lies somewhere in between, tempered with further judgments as to political and social impact. While this methodology meets the requirements of Task V, financial and schedule constraints precluded incorporation of this capability in the computer program and multiple sensitivity analyses could not be performed.

BASELINE

Source	1 - Normalized Inverse Composite Importance / 100			Amount Supplied		Expected Availability (lbs.)
Finland	=	(1 - .37)	X	1,350	=	850
Morocco	=	(1 - .47)	X	450	=	230
Botswana	=	(1 - 1.0)	X	250	=	0
S. Africa	=	(1 - 0.6)	X	150	=	60
Zaire	=	(1 - 1.0)	X	12,500	=	0
Zambia	=	(1 - 1.0)	X	3,500	=	0
Philippines	=	(1 - .77)	X	50	=	12
Australia	=	(1 - .77)	X	400	=	92
New Caledonia	=	(1 - .77)	X	250	=	58
Canada	=	(1 - .25)	X	1,100	=	825
U.S.	=	(1 - .28)	X	1,000	-	720
						2,856

FIGURE 9.

BASELINE

Source	1 - Normalized Inverse Composite Importance / 100			Amount Supplied		Expected Availability (lbs.)
Finland	= (1 - .37)	X		1,350	=	850
Morocco	= (1 - .47)	X		450	=	230
Botswana	= (1 - 1.0)	X		250	=	0
S. Africa	= (1 - 0.6)	X		150	=	60
Zaire	= (1 - .37)	X		12,500	=	7875
Zambia	= (1 - 1.0)	X		3,500	=	0
Philippines	= (1 - .77)	X		50	=	12
Australia	= (1 - .77)	X		400	=	92
New Caledonia	= (1 - .77)	X		250	=	58
Canada	= (1 - .25)	X		1,100	=	825
U.S.	= (1 - .28)	X		1,000	-	720
						10,722

FIGURE 10.

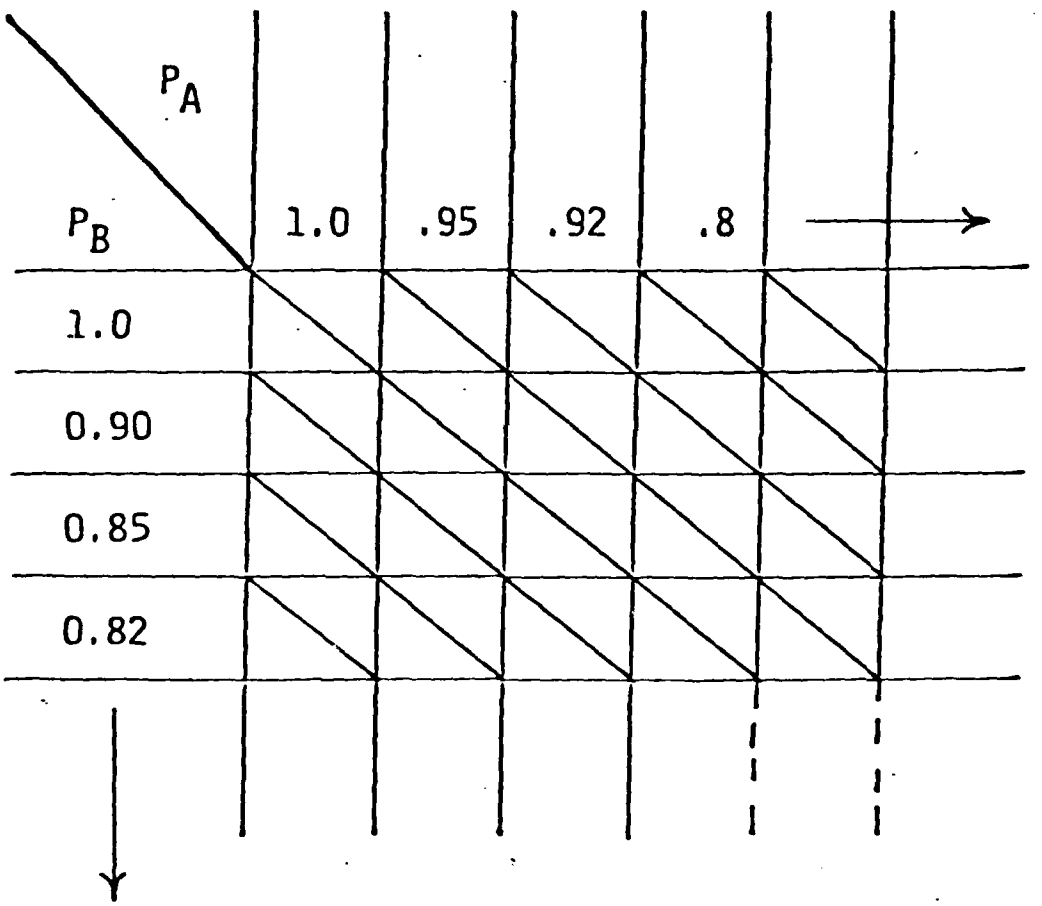
Task VI requires the structuring of the US/USSR purpose into a joint state space and the calculation of the worth of alternative moves. Since the ultimate value of stockpiles can only be seen in terms of the large scale interactions of the opposing superpowers, the game is defined by their purposes as these affect one another. This is the genesis of the joint state space.

Once the purpose of each of these nations is specified in the form of a hierarchic valuated state space and appropriate normalizing function (see Appendix E), the state vectors are mapped into a discrete scalar. It is useful to represent this function as a dimension of the joint state space so that each of the cells in this space represents a situation which is different from either or both players' points of view. Each situation has a worth to each of the players so that there are two payoffs for each cell (see Figure 11).

In the lower right-hand corner such games are generally cooperative. They become ambivalent in the mid-range and highly competitive in the upper left-hand corner. At the extreme off-diagonals, the game is one-sided and becomes one of oppression or submission, depending on the corner. The specific joint payoff function for each of the players can be constructed by examining the manner in which the marginal worth is transformed into a joint payoff by the existence of the other player. For example, the joint payoff to the

FIGURE 1i.

DISCRETE SCALAR



player represented across the very top becomes his marginal payoff when the opposing player ceases to exist [the lowest row for the opposing player (unless, of course, there is some extra value attained for having caused that demise or lower value for taking the blame)]. In contrast, the highest payoff may occur at the top of the column, if this is indeed a cooperative game.

Unfortunately, the individual purposes of the superpowers are highly complex so that the entire joint state space is enormous. By convention, the player of concern is represented across the top while the opposing player is on the left side. In this case, the player of concern is the Soviet Union (in that we are attempting to discover moves they might make in view of our stockpile deficiencies).

It will be most worthwhile to focus attention on that portion of the joint state space which is relevant to our interest. This can be done in three ways. First, there may well be natural groupings of values on the scalar that represent the overall worth of the individual states for each of the players. Recognition of these natural groups allows viewing the joint state space in a coarser mode with least loss of information. The question becomes, "What gross state are we in, and, What gross states can we get to by various moves (commitment of resources)?" Once these are compared, a more fine grained analysis can be performed. A second

method for reducing the joint state space is through dropping all states in the state space which are not likely to be of interest. For example, if the game is cooperative, all states to the right and below the present state are of little or of no interest. If the game is competitive, all states that do not lead to the appropriate corner are of little or no interest. If the player is ambivalent, it is pointless to consider all states to the right of the present position. In this manner the joint state space can be greatly reduced in size and scope.

The third method is more directly pertinent to the issue at hand. Here the individual purposes are tailored relative to that issue. Only the relevant factors are explicated for detailed consideration. For example, the propagation of Communist ideology is of fundamental interest to the Soviets, but this has little bearing on our critical resource stockpile deficiencies. For that reason, this portion of their purpose is essentially treated as an invariant in the analysis. The result is an issue-dependent reduced joint state space which may still be of considerable size but is directly pertinent if the issue at hand is to be adequately treated. Note that the other two methods of reducing a state space are still available for use (preferably truncating the state space before using the natural groupings).

Further, it is important to recognize that the payoff of all of the states in this space need not be computed once the nature of the payoff function is recognized. It is only necessary to compute the payoff in the present state and those states that would be entered for each of the moves and countermoves. The next step is to identify the present state and the allocable resources at this moment in the game (these in combination define the available moves). Certain combinations of these resources might seem particularly appropriate. Determination of their worth as an initial move requires generating the scenarios that grow out of this move (the expected countermoves). Each such scenario corresponds with a trajectory in the joint state space and thus a set of payoffs. The worth of this initial move can then be found. Scenarios which define alternative moves are then described and their worths calculated. Alternative moves can then be compared to determine the best allocation of resources in the light of the actions of the adversary.

RESEARCH ACCOMPLISHED

To ensure that the FEMA planners can select and implement the best alternatives in the face of conflicting goals, limited resources and a fluid international situation, it is imperative that they have the tools available to interrelate military and financial resources, needs of the forces, commodity availability and the pertinent factors relative to the commodity sources. Moreover, the decisions must be made now to ensure national security in an uncertain future with pressures in the national and international arenas which may not allow optimum actions.

The methodology developed by Decision Science provides a quantitative approach to complement current FEMA models and is a key analytic tool for simulating various strategies relative to the stockpiling function. Evaluation of the results of the various scenarios, which link the diverse factors of forces, materials and geography, will aid immensely in the decision process. Further, the top-down view employed by the Decision Science methodology ensures that decisions are not made in isolation from the very real influences of the international scene.

Specific areas of capability are discussed below, in the context of the 47 scenarios which are included at Appendix D. Pertinent data to illustrate the various points has been

extracted and is presented in tabular form. It must be noted, however, that these scenarios are not exhaustive. Rather, they show the range of capabilities which will be available to assess through simulation the impact of potential decisions regarding the stockpile and ultimately the security of the United States.

Joint Purpose

The first element within the Decision Science methodology is the degree of achievement of national purpose, by level of conflict. This is the key factor in the calculation of relative importance and ultimately the source/commodity importance. Up to this point, and in fact to initialize the model for this study, the achievement of purpose of the United States has been considered in isolation from the moves and countermoves which would be inevitable in stockpiling decisions. For the first time, an interrelational capability has been structured which views the achievement of worth of our national purpose in light of initiatives or responses on the part of the enemy. We are thus able to select available moves based on the allocable resources (or combination of resources), play the result through the Decision Science model and observe the effects on the stockpile factors.

Four scenarios relating the individual purposes of the U.S. and U.S.S.R. were constructed and are presented in

Appendix E. In these particular cases, the player of concern is the Soviet Union and is represented across the top of the discrete scalar. The moves are made on the part of the U.S.S.R. in the first three scenarios, with a postulated U.S. response in the fourth. Note that the lot of the U.S. steadily worsens, as measured by achievement of national purpose, with each move by the U.S.S.R., through the first three scenarios. In Scenario 4, the U.S. response includes strengthening our collective security and assistance to the Third World (i.e., the allocation of resources), with a concomitant improvement in achievement of national purpose. However, since the Soviet moves have still maintained our access to raw materials in some jeopardy, our payoff would be less than our calculated value. This value, which reflects the real world, would then be entered in the model and the results determined.

As noted in Appendix E, the joint payoff functions and the interactive coupling have been deferred for addressal in the follow-on study.

Source Vulnerability

The magnitude of the stockpile requirement is dependent to a great degree on the perceived and/or actual vulnerability of the source. Current resource strategies and stockpile planning factors are based on a static evaluation of the political reliability. An interactive evaluation is not available

to assess the strategies relative to the major powers, regional importance or source governments. There is a need to be able to assess this criticality of the source in light of how much they supply and of what material. Instead of an approach which sets somewhat arbitrary cut-off points relative to commodity availability, the source and commodity should be considered as a totality and their importance to the U.S. posture determined.

The Decision Science methodology considers the subject of vulnerability in terms of the importance attached to the source (i.e., regional weights), the application of military assets and the effects of these on the force elements. The net measure of merit is the source importance, which is the indicator of where national attention should be placed vis a vis strategic and critical materials and how might we be affected if our fiscal and/or military policies are changed. The results of eleven scenarios are compared to the base line in Figure 12. Five source/commodity pairs were selected to illustrate the results.

Scenarios 2, 3, and 4 deal with increased third world importance through provision of financial aid, for example, as well as the movement of forces from Europe to the third world. Scenarios 5, 6, 7, and 8 show the results of applying resources selectively to a specific country, in this case, Zaire. Scenarios 44-47 represent the reverse, that is reducing the importance we militarily ascribe to a country and deletion of a country as a source.

MEASURE OF MERIT \ SCENARIO	1	2	3	4	5	6
FORCE ELEMENT IMPORTANCE (Air Interdiction)	8.266 * (2)	7.868 (2)	8.470 (2)	8.061 (2)	8.266 (2)	7.868 (2)
FORCE ELEMENT IMPORTANCE (Army Ground)	7.382 (3)	6.845 (3)	6.372 (3)	6.035 (3)	7.382 (3)	6.845 (3)
FORCE ELEMENT IMPORTANCE (ROF)	3.706 (7)	4.146 (6)	4.249 (6)	3.913 (7)	3.706 (7)	4.146 (6)
FORCE ELEMENT IMPORTANCE (Special OPS)	.725 (19)	1.050 (16)	1.041 (16)	.753 (19)	.725 (19)	1.050 (16)
FORCE ELEMENT IMPORTANCE (Surface Comb.)	4.249 (5)	4.292 (5)	4.508 (5)	4.523 (5)	4.249 (5)	4.292 (5)
COMMODITY IMPORTANCE (Cobalt)	34.99	33.9	34.49	34.13	34.99	33.99
CRITICALITY OF SHORTFALL (Cobalt)	7.8	7.8	7.7	7.7	7.8	7.8
SOURCE IMPORTANCE (Country/Rank/ Value)	Z/1/100.0 ZA/4/28.0 K/2/37.44 C/5/26.14 F/15/4.0	Z/1/100.0 ZA/9/28.0 K/5/38.2 C/2/71.8 F/15/11.0	Z/1/100.0 ZA/9/28.0 K/6/37.8 C/2/72.1 F/15/11.0	Z/1/100.0 ZA/4/28.0 K/2/37.9 C/5/26.4 F/15/4.0	Z/1/100.0 ZA/4/70.9 K/2/94.8 C/5/66.2 F/16/10.1	Z/1/100.0 ZA/9/27.5 K/5/37.5 C/2/70.5 F/15/10.8
FORCE SUBELEMENT IMPORTANCE/OVERALL (Subelement/Raw Values/ Normalized)	F/3.05/8.7 M/2.03/3.7 S/.63/1.14	F/2.91/8.6 M/1.89/3.6 S/.63/1.2	F/3.13/8.07 M/1.76/3.12 S/.66/1.17	F/2.98/8.43 M/1.66/3.1 S/.67/1.25	F/3.05/8.7 M/2.03/3.7 S/.63/1.14	F/2.91/8.6 M/1.89/3.6 S/.63/1.2

* RANK is shown in parenthesis.

GENERIC REGION IMPORTANCES

Scenario Descriptor

IMPACT OF REGION IMPORTANCE

1. Baseline - Data Base Region Importance, Commodity Sources, Commodity Amounts and Force Element Designations.
2. Increased Third World Region Importance.
3. Increased Third World Region Importance; Forces Moved to Third World.
4. Baseline Region Importance; Forces Moved to Third World.
5. Baseline Region Importance; Zaire Land and Air Media Importance Raised.
6. Increased Third World Region Importance; Zaire Land and Air Media Importance Raised.

F = FINLAND/COBALT

Z = ZAIRE

ZA = ZAMBIA

K = KENYA

C = CANADA/NICKEL

F = F-16/AIR INTERDICTION

M = M-1

S = SH-2

FIGURE 12A

34A

SCENARIO / MEASURE OF MERIT	1	7	8	44	45	46	47
FORCE ELEMENT IMPORTANCE (Air Interdiction)	8.266 * (2)	8.266 (2)	7.868 (2)	8.266 (2)	7.868 (2)	8.266 (2)	8.266 (2)
FORCE ELEMENT IMPORTANCE (Army Ground)	7.382 (3)	7.382 (3)	6.845 (3)	7.382 (3)	6.845 (3)	7.382 (3)	7.382 (3)
FORCE ELEMENT IMPORTANCE (RDF)	3.706 (7)	3.706 (7)	4.146 (6)	3.706 (7)	4.146 (6)	3.706 (7)	3.706 (7)
FORCE ELEMENT IMPORTANCE (Special OPS)	.725 (19)	.725 (19)	1.05 (16)	.725 (19)	1.05 (16)	.725 (19)	.725 (19)
FORCE ELEMENT IMPORTANCE (Surface Comb.)	4.249 (5)	4.249 (5)	4.292 (5)	4.249 (5)	4.292 (5)	4.249 (5)	4.249 (5)
COMMODITY IMPORTANCE (Cobalt)	34.99	34.99	33.99	34.99	33.99	34.99	34.99
CRITICALITY OF SHORTFALL (Cobalt)	7.8	7.8	7.8	7.8	7.8	7.8	7.8
SOURCE IMPORTANCE (Country/Rank/ Value)	Z/1/100.0 ZA/4/28.0 K/2/37.44 C/5/26.14 F/15/4.0	Z/2/98.96 ZA/4/74.8 K/1/100.0 C/5/69.8 F/16/10.7	Z/1/100.0 ZA/9/27.5 K/5/37.5 C/2/70.5 F/15/10.8	Z/1/100.0 ZA/4/28.0 K/2/37.4 C/5/26.14 F/11/10.8	Z/1/100.0 ZA/9/28.0 K/5/38.2 C/2/71.82 F/15/10.8	Z/1/100.0 ZA/4/26.0 K/2/35.04 C/5/24.5 F/0/0	Z/1/100.0 ZA/5/28.0 K/2/37.60 C/6/26.4 F/15/4.0
FORCE SUBELEMENT IMPORTANCE/OVERALL (Subelement/Raw Values/ Normalized)	F/3.05/8.7 M/2.03/3.7 S/.63/1.14	F/3.05/8.7 M/2.03/3.7 S/.63/1.14	F/2.91/8.6 M/1.89/3.6 S/.63/1.2	F/3.05/8.7 M/2.03/3.7 S/.63/1.14	F/2.91/8.6 M/1.89/3.6 S/6.3/1.2	F/3.05/8.7 M/2.03/3.7 S/6.3/1.14	F/3.05/8.7 M/2.03/3.7 S/.63/1.14

* RANK is shown in parenthesis.

GENERIC REGION IMPORTANCES

Scenario Descriptor

IMPACT OF REGION IMPORTANCE

1. Baseline - Data Base Region Importance, Commodity Sources, Commodity Amounts and Force Element Designations.
7. Baseline: Zaire Land, Air and Sea Media Importance Raised.
8. Increased Third World Region Importance: Zaire Land, Air and Sea Media Importance Raised.
44. Baseline: Finland Media Importances Reduced.
45. Increased Third World Region Importance; Finland Media Importances Reduced.
46. Baseline; Finland Deleted.
47. Baseline; South Africa Deleted.

F = FINLAND/COBALT
Z = ZAIRE
ZA = SAMBIA
K = KENYA
C = CANADA/NICKEL
F = F-16/AIR INTERDICTION
M = M-1
S = SH-2

FIGURE 12B

It can be seen that a country that supplies a major amount of critical material (e.g., Zaire/cobalt) will always rank high, which is intuitively satisfying. What is critical to note is the effect on other countries once we have applied these resources. The Canada/nickel combination rises in importance, showing that our integrated view of our stockpile situation has called another combination to our attention. Note that the simple movement of forces does not have a major impact, unless accompanied by an increase in regional importance, implying a change in national commitment. This in turn would subject the limited military resources to a strain in trying to support more territorial assignments with finite resources. Selective changes in resource allocation, in this case Zaire, had a major effect on the importance value of other country/commodity pairs, but not on the rankings. In other words, additional attention must be paid, but at the same prioritization.

The deletion of countries, either through political considerations (i.e., Finland subjugation to Soviet Union pressures) or nationalization (South Africa) was seen to have only minor effect, although this aspect needs further exploration.

Another area of interest as regards vulnerability is the effect on the force elements and their subelements. While the commodity importance and criticality of shortfall

considerations remain essentially the same, the force elements importance, sensitive to both regional importance and locale assignment, shift in both ranking and importance. As will be discussed later, this will change the prioritization of force elements in relation to their "access" to the stockpile.

The final point to be discussed here is the relationship of source vulnerability to amount of material supplied. As shown under "methods," the results of the above scenarios can be applied to give additional insight into actual amounts of material potentially available because of U.S. application of resources. While demonstrated, this will be coded as part of the follow-on study.

Substitution

If national actions cannot ensure the availability of material through existing or secure potential sources, then plans must be made for dealing with reduced sources, opening new sources, or finding the best substitution techniques. If a lesser amount of material can be accepted, the question is where to take the reduction in supply (i.e., large suppliers, many suppliers, etc.). On the other hand, what would be the effect of spending money to reduce the stockpile shortfall (or conversely, if for some reason the stockpile requirements were reduced). A third area for consideration is the requirement by force element for any given commodity. That is, if

money is to be spent to find substitutes for a material, which material is the best candidate. As before, the impact of the above will be assessed in terms of the source importances as they reflect the impact of decisions. This will be in the context of our baseline conditions and the changes in source importances resulting from changes in regional importances through applicaton of either financial or military resources.

Turning first to the impact of changing the amount of material (cobalt) by source and possibly opening a new source. The following comments are related to Figures 13, 14, and 15.

If the reduction is taken from a major source (Scenario 10), the effect is to suppress the importance of the other commodity suppliers, since Zaire is now even more predominate. If Zaire is reduced (Scenario 12), the major effect is on Zambia's importance, although the rank order is unchanged; the net result is that Zambia has risen in the need for national attention. If the minor countries are deleted (along with some reduction in Zambia to maintain the same commodity weight in the calculations), the result is a suppression of the other source importances from baseline, as in Scenario 10, but with Zambia importance reduced. The values are below Scenario 12. The result is that Zaire is predominate in all cases, but if the reduction is

SCENARIO / MEASURE OF MERIT	1	10	11	16	19	21	23	25
FORCE ELEMENT IMPORTANCE (Air Interdiction)	8.266	8.266	8.266	7.868	8.266	8.266	7.868	7.868
COMMODITY IMPORTANCE (Cobalt)	34.99	34.99	34.99	33.49	34.99	34.99	33.99	33.99
CRITICALITY OF SHORTFALL (Cobalt)	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8
SOURCE IMPORTANCE (Country, Rank, Value)	Z/1/100.0 K/2/37.4 C/5/26.1 ZA/4/28.0	Z/1/100.0 K/2/31.2 C/4/21.8	Z/1/100.0 K/2/37.4 C/4/26.1	Z/1/100.0 K/5/31.6 C/2/59.6	Z/1/100.0 K/2/84.2 C/4/58.8	Z/2/98.96 K/1/100.0 C/4/69.8	Z/1/100.0 K/5/31.2 C/2/58.7	Z/1/100.0 K/5/37.5 C/2/70.5
FORCE SUBELEMENT IMPORTANCE/Coblat (Subelement/Raw Value/Normalized)	F/71.9/8.7 M/67.8/5.2 S/15.2/1.2	F/71.9/C.7 M/67.6/5.2 S/15.19/1.47	F/71.9/8.7 M/67.8/5.2 S/15.19/1.17	F/68.4/8.6 M/62.86/5.1 S/15.17/1.23	F/71.8/8.7 M/62.8/5.2 S/15.2/1.87	F/71.9/8.7 M/67.8/5.2 S/15.19/1.17	F/68.4/8.6 M/62.9/5.1 S/15.2/1.23	F/68.4/8.6 M/62.9/5.1 S/15.17/1.23

NOTE: CRITICALITY OF SHORTFALL Differences Lost in Rounding Process.

FIGURE 13.

ZA = ZAMBIA
Z = ZAIRE
K = KENYA
C = CANADA(NICKEL)
F = F-16/AIR INTERDICTION
M = M-1
S = S.-2

SUBSTITUTION

Scenario Descriptor

CHANGE ZAMBIA SUPPLY

1. Baseline - Date Base Region Importance, Commodity Sources, Commodity Amounts and Force Element Designations.
10. Baseline; Reduce Zambia Cobalt by 3500#.
11. Baseline; Reduce Zambia Cobalt by 3500#, Increase U.S. Cobalt by 3500#.
16. Increased Third World *Region Importance*; Reduce Zambia Cobalt by 3500#.
19. Baseline; Zaire Media Importances Raised; Reduce Zambia Cobalt 3500#.
21. Baseline; Zaire Media Importances Raised; Reduce Zambia Cobalt 3500#, Increase U.S. Cobalt 3500#.
23. Increased Third World Region Importance; Zaire Media Importances Raised; Reduce Cobalt 3500#.
25. Increased Third World *Region Importance*; Zaire Media Importances Raised, Reduce Zambia Cobalt 3500# Increase U.S. Cobalt 3500#

38.

MEASURE OF MERIT \ SCENARIO	1	12	13	17	18	20	24
FORCE ELEMENT IMPORTANCE (Air Interdiction)	8.266	8.266	8.266	7.868	7.868	8.266	7.868
COMMODITY IMPORTANCE (Cobalt)	34.99	34.99	34.99	33.99	33.99	34.99	33.99
CRITICALITY OF SHORTFALL (Cobalt)	7.8	7.8	7.8	7.8	7.8	7.6	7.8
SOURCE IMPORTANCE (Country, Rank, Value)	Z/4/28.0 C/5/26.14 K/2/37.44	Z/48/38.9 C/5/30.3 K/2/26.1	Z/1/100 ZA/4/38.9 C/5/36.3 K/2/52	Z/3/38.9 C/2/83.1 K/5/44.2	Z/9/36.9 Z/2/99.8 K/5/53.1	ZA/3/89.7 C/5/69.8 K/1/100.0 Z/4/85.5	Z/8/38.2 C/2/81.6 K/5/43.4
FORCE SUBELEMENT IMPORTANCE/Cobalt (Subelement/Raw Value Normalized)	F/71.9/8.7 M/67.8/5.2 S/15.2/1.2	F/71.9/8.7 M/67.8/5.2 S/15.2/1.2	F/71.9/8.7 M/67.8/5.2 S/15.2/1.2	F/68.4/8.6 M/62.9/5.1 S/15.2/1.23	F/68.4/8.6 M/62.9/5.1 S/15.2/1.23	F/68.4/8.6 M/62.9/5.1 S/15.2/1.23	F/68.4/8.6 M/62.9/5.1 S/15.2/1.23

NOTE: CRITICALITY OF SHORTFALL Differences Lost in Rounding Process.

C = CANADA(NICKEL)
K = KENYA
Z = ZAMBIA
F = F-16/AIR INTERDICTION
M = M-1
S = SH-2

FIGURE 14.

SUBSTITUTION

Scenario Descriptor

CHANGE ZAIRE SUPPLY

1. Baseline - Data Base Region Importance, Commodity Sources, Commodity Amounts and Force Element Designations.
12. Baseline; Reduce Zaire Cobalt by 3500#.
13. Baseline; Reduce Zaire Cobalt by 3500#, Increase U.S. Cobalt by 3500#.
17. Increased Third World Region Importance; Reduce Zaire Cobalt by 3500#.
18. Increased Third World Importance; Reduce Zaire Cobalt by 3500#. Increase U.S. by 3500#.
20. Baseline; Zaire Media Importances Raised; Reduce Zaire Cobalt 3500#.
24. Increased Third World Region Importance; Zaire Media Importances Raised, Reduce Zaire Cobalt 3500#.

39.

MEASURE OF MERIT \ SCENARIO	1	14	15	22	26
FORCE ELEMENT IMPORTANCE (Air Interdiction)	8.266	8.266	8.266	8.266	7.868
COMMODITY IMPORTANCE (Cobalt)	34.99	34.99	34.99	34.99	33.99
CRITICALITY OF SHORTFALL (Cobalt)	7.8	7.8	7.8	7.8	7.8
SOURCE IMPORTANCE (Country/Rank/ Value)	Z/1/100.0 ZA/4/28.0 K/2/37.4 C/5/26.1	Z/1/100.0 ZA/4/23.2 K/2/31.2 C/5/21.8	Z/1/100.0 ZA/4/32.2 K/2/43.3 C/5/30.3	Z/1/100.0 ZA/4/62.6 K/2/84.2 C/5/58.8	Z/1/100.0 ZA/9/22.8 K/5/31.4 C/2/58.7
FORCE SUBELEMENT IMPORTANCE/Cobalt (Subelement/Raw Value/Normalized)	F/71.9/8.7 M/67.8/5.2 S/15.19/1.17	F/71.8/8.7 M/67.8/5.2 S/15.19/1.17	F/71.8/8.7 M'67.8/5.2 S/15.19/1.17	F/71.9/2.7 M/67.8/5.2 S/15.19/1.17	F/68.4/8.6 M/62.9/5.1 S/15.17/1.23

FIGURE 15.

SUBSTITUTION

Scenario Descriptor

DELETE MINOR COBALT COUNTRIES

1. Baseline - Data Base Region Importance, Commodity Sources, Commodity Amounts and Force Element Designations.

14. Baseline; Reduce "Minor Country" and Zambia Cobalt by 3500#.

15. Baseline; Reduce "Minor Country", Zambia and Zaire Cobalt by 7000#.

22. Baseline; Zaire Media Importances Raised; Delete "Minor Countries"/Zambia Cobalt 3500#.

26. Increased Third World Region Importance; Zaire Media Importance Raised, Delete "Minor Country"/Zambia Cobalt 3500#.

ZA = ZAMBIA
Z = ZAIRE
K = KENYA
C = CANADA(NICKEL)

F = F-16/AIR INTERDICTION
M = M-1
S = SH-2

taken from Zaire rather than from Zambia or the minor countries, the importance of the other countries increases, indicating the need for additional attention. The decision would be to not reduce Zaire, if given a choice. The selection would be to take the amount from Zambia, since the other two sources considered in this brief analysis maintain the same importance values in the two scenarios.

The preceding discussion presumed that the lesser amount of cobalt could be tolerated. The next two scenarios considered the reduction of source amounts with the need to open a new supply source (in this case, the U.S., but any country could be addressed). If Zambia is decreased (Scenario 11), there is no change in the other two countries from baseline (there is, of course, an increase in U.S. importance, which is an internal consideration). If Zaire is decreased (Scenario 13), there is a pronounced increase in the importance of the other two countries (and a lesser increase in the U.S.). The message in this set of scenarios is again to take the reduction from Zambia.

An excursion (Scenario 15) looked at our overall reduction in supply while still opening a new source. The net result was similar to reduction in Zaire, but with the importance of Zambia reduced. Additional scenarios must be run to address these points.

The next area reviewed considered the above set of scenarios, except that resources were applied to increase

the importance of the region and/or a specific source. The comments again refer to Figures 13, 14 and 15.

Scenarios 16 and 17 consider the reduction in supply from Zambia and Zaire, respectively, when the regional importance of the third world is increased. The values for third world countries in this analysis are not changed drastically from the baseline. However, Canada/nickel importance has a large increase in importance, indicating that the methodology provides pointers to other critical areas as limited resources are applied (compare to Scenarios 10 and 12). Where third world importance is increased and a new source is opened to cover the loss of Zaire cobalt (compare Scenario 18 to 15), there is an increase in other third world country importances, with another significant increase in Canadian/nickel worth. Within the top down view of the interacting considerations which make up the stockpile decisions, attention has been brought to focus on another area. Uniquely, this source/commodity pair is a friendly nation with well assigned military assets. Hence, further analysis would assess this as a safe source.

The next area considers the application of resources to an individual source (in this case, Zaire) and our national purpose assessed in this light. Here again, comparisons can be made between Scenarios 19 and 20 and Scenarios 16 and 17 showing that the primary changes are in other third world countries with Canada being less

fluid. It is interesting to note here that this allocation of national resources actually results in Zaire being supplanted as the preeminent source, clearly demonstrating the model sensitivity. Further comparisons are straightforward and will not be discussed.

The model also addresses the effects of changing the commodity stockpile requirements. The scenarios cataloged in Figure 16 consider the reduction of the shortfall for nickel and cobalt and the reduction of the cobalt shortfall under conditions of applied resources to various geographical regions.

Scenario 27 (reduced cobalt shortfall) and Scenario 28 (reduced nickel shortfall) have been constructed so each has the same percentage of commodity shortfall. At the baseline region importance, only modest changes are observed in source importance values and rankings. The normalizing process shows a change in Zambia rank and increases in the importance of Kenya and Canada as the cobalt stockpile shortfall is reduced. When the nickel shortfall is reduced, the model results in a clearly defined decrease in the Canada/nickel source pair importance. For the case of applied resources to the third world areas (Scenarios 29 and 30), very distinct movements are observed as other source/commodity pairs shift in importance.

As shown in Figure 17, four scenarios were run which considered combinations of regional importances, assignment

SCENARIO / MEASURE OF MERIT	1	27	28	29	30
FORCE ELEMENT IMPORTANCE (Air Interdiction)	8.266	8.266	8.266	8.266	7.868
COMMODITY IMPORTANCE (Cobalt)	34.99	34.99	34.99	34.99	33.99
COMMODITY IMPORTANCE (Nickel)	41.21	41.21	41.21	41.21	40.30
CRITICALITY OF SHORTFALL (Cobalt)	7.8	7.1	9.1	7.1	7.1
CRITICALITY OF SHORTFALL (Nickel)	10.0	10.0	9.8	10.0	10.0
SOURCE IMPORTANCE (Country/Rank/ Value)	Z/1/100.0 ZA/4/28.0 K/2/37.4 C/5/26.1	Z/1/100.0 ZA/5/28.0 K/2/41.2 C/4/28.7	Z/1/100.0 ZA/4/28.0 K/2/37.4 C/7/21.9	Z/3/90.03 ZA/5/68.04 K/1/100 C/4/69.8	Z/1/100.0 ZA/9/27.47 K/5/41.2 C/2/77.45
FORCE SUBELEMENT IMPORTANCE/OVERALL (Subelement/Raw Value/Normalized)	F/3.1/8.7 M/2.03/3.7 S/.63/1.14	F/3.1/8.7 M/2.03/3.7 S/.63/1.14	F/3.1/8.7 M/2.03/3.7 S/.63/1.14	F/3.05/8.7 M/2.03/3.7 S/.63/1.14	F/2.91/8.6 M/1.89/3.6 S/.63/1.2

FIGURE 16.

NOTE: Shifts in SHORTFALL CRITICALITY are at lower levels than the Normalized Values for Nickel and Cobalt Show.

SUBSTITUTION

Scenario Descriptor

REDUCE COMMODITY STOCKPILE REQUIREMENT

1. Baseline - Date Base Region Importance; Commodity Sources, Commodity Amounts and Force Element Designations.

27. Baseline; Reduce Cobalt Stockpile Requirement to 50 Units.

28. Baseline; Reduce Nickel Stockpile Requirement to 37 Units.

29. Baseline; Zaire Media Importances Raised; Reduce Cobalt Stockpile Requirement to 50 Units.

30. Increased Third World Region Importance; Zaire Media Importances Raised; Reduce Cobalt Stockpile Requirement to 50 Units.

Z = ZAIRE
ZA = ZAMBIA
K = KENYA
C = CANADA(NICKEL)
F = F-16/AIR INTERDICTION
M = M-1
S = SH-2

of forces and variations in commodity amounts available from two sources. It can be noted that Canada/nickel is sensitive to the application of resources in the third world regime, while Finland/cobalt shows a response to essentially three of the four actions. As before, the comparisons are straightforward and will not be addressed in greater detail here.

The final area relative to substitution is a change in commodity importances to the force elements, which considers the relationship of the commodities to the subelements using the structure detailed in Appendix B. Several scenarios, which consider the effects of changing commodity importances, both with and without changes in regional importance, are cataloged in Figure 18.

Scenarios 31, 33, 36, and 37 consider the effects of reducing the importance of specific commodities to specific subelements within the four force elements. The movement of source importances is as expected, within the following considerations. First, the importance of cobalt results in the effects being observed in the movement of other sources, whereas changes in nickel and pyrethrum, for instance, are observed directly. Second, the comparisons can be considered as indicative only, since they will undoubtedly vary as additional force elements are decomposed to their subelements.

Changes in regional importances result in the same types of movement as discussed in preceding paragraphs.

MEASURE OF MERIT \ SCENARIO	1	40	41	42	43
FORCE ELEMENT IMPORTANCE (Air Interdiction)	8.266 * (2)	8.061 (2)	8.061 (2)	8.470 (2)	8.470 (2)
FORCE ELEMENT IMPORTANCE (Army Ground)	7.382 (3)	6.035 (3)	6.035 (3)	6.372 (3)	6.372 (3)
FORCE ELEMENT IMPORTANCE (RDF)	3.706 (7)	3.913 (7)	3.913 (7)	4.249 (6)	4.249 (6)
FORCE ELEMENT IMPORTANCE (Special OPS)	0.725 (19)	0.753 (19)	0.753 (19)	1.041 (16)	1.041 (16)
FORCE ELEMENT IMPORTANCE (Surface Comb.)	4.249 (5)	4.523 (5)	4.523 (5)	4.508 (5)	4.508 (5)
COMMODITY IMPORTANCE (Cobalt)	34.99	34.13	34.13	34.49	34.49
CRITICALITY OF SHORTFALL (Cobalt)	7.8	7.7	7.7	7.7	7.7
SOURCE IMPORTANCE (Country/Rank/ Value)	Z/1/100.0 ZA/4/28.0 K/2/37.44 C/5/26.14 F/15/4.0	Z/1/100.0 ZA/0/0 K/2/31.6 C/4/22.0 F/14/4.17	Z/1/100.0 ZA/4/38.9 K/2/43.9 C/5/30.6 F/15/5.66	Z/1/100.0 ZA/0/0 K/6/31.47 C/2/60.11 F/12/11.0	Z/1/100.0 ZA/8/38.9 K/6/43.7 C/2/63.5 F/13/15.3
FORCE SUBELEMENT IMPORTANCE/ OVERALL (Subelement/Raw Value/Normalized)	F/3.05/8.7 M/2.03/3.7 S/.63/1.14	F/2.98/8.43 M/1.66/3.1 S/.67/1.25	F/2.98/8.43 M/1.66/3.1 S/.67/1.25	F/3.13/8.07 M/1.76/3.12 S/.66/1.17	F/3.13/8.07 M/1.76/3.12 S/.66/1.17

FIGURE 17.

* RANK Shown in Parenthesis.

NOTE: CRITICALITY OF SHORTFALL Differences Lost in Rounding Process.

COMBINATION SCENARIOS

Scenario Descriptor

IMPACT OF COMBINED CHANGES IN REGION IMPORTANCE, MOVEMENT OF FORCES, AND COMMODITY AMOUNTS

1. Baseline - Data Base Region Importance, Commodity Sources, Commodity Amounts and Force Element Designations.

40. Baseline; Forces Moved to Third World; Reduce Zambia Cobalt 3500#.

41. Baseline; Forces Moved to Third World; Reduce Zaire Cobalt 3500#.

42. Increased Third World Region Importance; Forces Moved to Third World.

43. Increased Third World Region Importance; Forces Moved to Third World; Reduce Zaire Cobalt 3500#.

ZA = ZAMBIA

Z = ZAIRE

K = KENYA

C = CANADA(NICKEL)

F = FINLAND/COBALT

F = F-16/AIR INTERDICTION

M = M-1

S = SH-2

MEASURE OF MERIT \ SCENARIO	1	31	32	33	34	35	36	37	38	39
FORCE ELEMENT IMPORTANCE (Air Interdiction)	8.266	8.266	7.868	8.266	8.266	7.868	8.266	8.266	7.868	8.266
FORCE ELEMENT IMPORTANCE (Army Ground)	7.382	7.382	6.845	7.382	7.382	6.845	7.382	7.382	6.845	7.382
COMMODITY IMPORTANCE (Cobalt)	34.99	29.97	29.21	34.99	29.97	29.21	34.99	33.44	32.36	34.59
COMMODITY IMPORTANCE (Nickel)	41.21	41.21	40.30	36.26	41.21	40.30	41.21	41.21	40.30	41.04
COMMODITY IMPORTANCE (Pyrethrum)	17.08	17.08	16.92	17.08	17.08	16.92	14.60	17.08	16.92	17.15
CRITICALITY OF SHORTFALL (Cobalt)	7.8	6.7	6.7	8.9	6.7	6.7	7.8	7.4	7.4	7.8
CRITICALITY OF SHORTFALL (Nickel)	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
CRITICALITY OF SHORTFALL (Pyrethrum)	4.3	4.3	4.4	4.9	4.3	4.4	3.7	4.3	4.3	4.3
SOURCE IMPORTANCE (Country/Rank/ Value)	Z/1/100.0 ZA/4/28.0 K/2/37.4 C/5/26.1	Z/1/100.0 ZA/6/28.0 K/2/43.76 C/4/30.54	Z/1/100.0 ZA/9/28.0 K/5/44.5 C/2/83.6	Z/1/100.0 ZA/4/28.0 K/2/37.4 C/6/23.0	Z/3/84.6 ZA/6/64.1 K/1/100 C/4/69.8	Z/1/100.0 ZA/9/27.5 K/5/43.6 C/2/81.98	Z/1/100.0 ZA/4/28.0 K/2/32.0 C/5/26.14	Z/1/100.0 ZA/4/28.0 K/2/39.4 C/5/27.5	Z/1/100.0 ZA/9/28.0 K/5/40.1 C/2/75.4	Z/1/100.0 ZA/4/28.0 K/2/38.03 C/5/26.3
FORCE SUBELEMENT IMPORTANCE/OVERALL (Subelement/Raw Value/Normalized)	F/3.1/8.7 M/2.03/3.7 S/.6/1.14	F/2.61/8.7 M/2.03/4.3 S/.54/1.16	F/2.48/8.6 M/1.89/4.22 S/.54/1.21	F/2.61/8.7 M/2.03/4.3 S/.52/1.11	F/2.61/8.7 M/2.03/4.3 S/.54/1.16	F/2.48/8.6 M/1.89/4.2 S/.54/1.21	F/3.05/8.7 M/2.03/3.7 S/.63/1.14	F/3.05/8.7 M/1.62/2.8 S/.63/1.14	F/2.91/8.6 M/1.47/2.8 S/.63/1.2	F/3.24/10 M/2.03/4.13 S/.57/1.15

SUBSTITUTION

Scenario Descriptor

CHANGE COMMODITY IMPORTANCE TO SUBELEMENTS

1. Baseline - Data Base Region Importance, Commodity Sources Commodity Amounts and Force Element Designations.
31. Baseline; Reduce Importance of Cobalt to Jet Aircraft.
32. Increased Third World Region Importance; Reduce Importance of Cobalt to Jet Aircraft.
33. Baseline; Reduce Importance of Nickel to Jet Aircraft.
34. Baseline; Zaire Media Importances Raised; Reduce Importance of Cobalt to Jet Aircraft.
35. Increased Third World Region Importance; Zaire Media Importances Raised; Reduce Importance of Cobalt to Jet Aircraft.
36. Baseline; Reduce Importance of Pyrethrum to the Forces.
37. Baseline; Reduce Importance of Cobalt to M-series.
38. Increased Third World Region Importance; Reduce Importance of Cobalt to M-series.
39. Baseline; Reduce Importance of Aircraft Subelement Cobalt Users to the Force Elements.

Z = ZAIRE
ZA = ZAMBIA
K = KENYA
C = CANADA (NICKEL)
F = F-16/AIR INTERDICTION
M = M-1
S = SH-2

FIGURE 18.

A final area of interest is the change in subelement importance (e.g., jet aircraft) to the force element (Scenario 39). The resultant shift from baseline importances is small, suggesting that source/commodity importance are more strongly related to the relationship of a commodity to the subelement than the relationship of the subelement to its parent force element. Additional scenarios which consider other commodities will be necessary to address this point.

Prioritization

Another item of major concern to the decision maker is the prioritization of requirements, given any specific condition or situation. For instance, what is the importance of a given commodity and what effect does a decision have? Force element importance is a function of regional importances and assignment of forces as can be observed in Figures 12 through 18. However, commodity importance is also directly related to its requirement by the subelement of the force elements and thus as these importances change there is a change in commodity importance. This interrelationship can be noted for cobalt importance in Scenarios 1, 2, 31, and 35 with respective values of 34.99, 33.99, 29.27, and 29.21. These values (normalized with the other commodities) are then direct inputs to the calculation of the normalized force element/shortfall criticality which considers the

state of the stockpile with the importance of the force element/commodity. Again, the result is a prioritization of the strategic material which relates sources, commodities, and military users. Perusal of Figure 18 reveals the movement of this value for various situations.

The methodology can be exercised to show the relationship of the subelements by individual commodity and overall commodities. These conditions are shown for the Baseline and increased region importances in Figure 19 for cobalt and all commodities. Note that for cobalt the subelement importance ranking changes for F-18, S-3, and A-10 between the two scenarios. For all commodities the attack submarine and SH-60B move up. Thus, the methodology will provide a prioritization ranking for access to commodities based on the importance of the commodity to the subelement. In Figure 20, it is noted that the result of substitution (i.e., the reduction of the importance of cobalt to jet aircraft) has a very marked effect on the ranking and hence the priority of access to a particular commodity (cobalt). For all commodities, although the aircraft again lead the rankings because of our interrelated view of importances, other subelements, such as the M-1, have increased in quantitative value.

As discussed earlier, only five commodities were analyzed while the subelements addressed here relate to

SUBELEMENT RELATIONSHIPS

Scenario 1.
BASELINE

COBALT

NORMALIZED VALUES	
F-111	10.0000
F-16	8.6787
F-4	8.5622
A-10	5.6216
F-18	5.5556
M-1	5.2402
M-60	4.7162
F-15	4.4444
M-901	4.1921
A-7	4.0000
COBRA	3.7478
M-2/M-3	3.6681
F-14	3.3333
A-6	3.0000
M-48	2.9345
MORTERS	2.8530
SELF-PROP.	2.7948
S-3	2.6842
GLCMS	2.3290
TOWED ART.	2.0961
ATT. SUBS	1.8640
SH-60B	1.8267
MLRS	1.5721
PERSHING	1.3974
SH-2	1.1743
FRIGATES	1.1184
DSTROYERS	0.6710
INFANTRY	0.5822
SH-3	0.4697
RADIO RLAY	0.4608
M-113	0.4076
ART. ACRFT	0.2811
RCLES LNCH	0.1223
M-551	0.0175

ALL COMMODITIES

NORMALIZED VALUES	
F-111	10.0000
F-16	8.6787
F-4	8.0585
F-18	5.8824
A-10	5.6216
F-15	4.4444
INFANTRY	4.3839
A-7	4.0000
COBRA	3.8213
M-1	3.6989
M-60	3.6989
F-14	3.5294
A-6	3.0882
SELF-PROP.	2.9592
M-2/M-3	2.9592
M-901	2.9592
S-3	2.6842
M-48	2.3016
ATT. SUBS	2.2807
TOWED ART.	2.2194
MORTERS	2.2057
GLCMS	1.9180
SH-60B	1.9035
FRIGATES	1.3684
PERSHING	1.2330
MLRS	1.2330
SH-2	1.1447
DSTROYERS	0.8210
SH-3	0.4579
RADIO RLAY	0.4337
M-113	0.4110
ART. ACRFT	0.2425
RCLES LNCH	0.0411
M-551	0.0233

Scenario 2.
INCREASED THIRD WORLD REGION IMPORTANCE

COBALT

NORMALIZED VALUES	
F-111	10.0000
F-16	8.5962
F-4	8.5473
F-18	5.5556
A-10	5.4732
M-1	5.1042
M-60	4.5938
F-15	4.4444
M-901	4.0834
A-7	4.0000
COBRA	3.6488
M-2/M-3	3.5729
F-14	3.3333
A-6	3.0000
M-48	2.8583
S-3	2.8158
MORTERS	2.7789
SELF-PROP.	2.7222
GLCMS	2.2685
TOWED ART.	2.0417
ATT. SUBS	1.9554
SH-60B	1.9163
MLRS	1.5313
PERSHING	1.3611
SH-2	1.2319
FRIGATES	1.1732
DSTROYERS	0.7039
INFANTRY	0.5671
SH-3	0.4928
RADIO RLAY	0.4552
M-113	0.3970
ART. ACRFT	0.2737
RCLES LNCH	0.1191
M-551	0.0170

ALL COMMODITIES

NORMALIZED VALUES	
F-111	10.0000
F-16	8.5962
F-4	8.0445
F-18	5.8824
A-10	5.4732
F-15	4.4444
INFANTRY	4.2702
A-7	4.0000
COBRA	3.7204
M-1	3.6030
M-60	3.6030
F-14	3.5294
A-6	3.0882
M-2/M-3	2.8824
M-901	2.8824
SELF-PROP.	2.8824
S-3	2.8158
ATT. SUBS	2.2236
M-48	2.2418
TOWED ART.	2.1618
MORTERS	2.1484
SH-60B	1.9968
GLCMS	1.8682
FRIGATES	1.4355
PERSHING	1.2010
MLRS	1.2010
SH-2	1.2008
DSTROYERS	0.8613
SH-3	0.4803
RADIO RLAY	0.4285
M-113	0.4003
ART. ACRFT	0.2361
RCLES LNCH	0.0400
M-551	0.0227

FIGURE 19.

Scenario 35.

INCREASED THIRD WORLD AND ZAIRE IMPORTANCE
REDUCE IMPORTANCE OF COBALT TO JET AIRCRAFT

COBALT

NORMALIZED VALUES	
M-1	10.0000
M-60	9.0000
M-901	8.0000
F-111	7.3469
M-2/M-3	7.0000
F-16	6.3156
F-4	6.2796
M-48	5.6000
MORTERS	5.4444
SELF-PROP.	5.3333
GLCMS	4.4444
F-18	4.0816
A-10	4.0211
TOWED ART.	4.0000
ATT. SUBS	3.8309
COBRA	3.5743
F-15	3.2653
MLRS	3.0000
A-7	2.9388
PERSHING	2.6667
F-14	2.4490
FRIGATES	2.2986
A-6	2.2041
S-3	2.0687
SH-60B	1.6090
DSTROYERS	1.3791
INFANTRY	1.1111
SH-2	1.0344
RADIO RLAY	0.8919
M-113	0.7778
ART. ACRFT	0.5361
SH-3	0.4137
RCLES LNCH	0.2333
M-551	0.0333

ALL COMMODITIES

NORMALIZED VALUES	
F-111	10.0000
F-16	8.5962
F-4	7.9579
F-18	5.9387
A-10	5.4732
INFANTRY	5.0064
F-15	4.4444
M-1	4.2242
M-60	4.2242
A-7	4.0000
COBRA	3.8585
F-14	3.5632
M-2/M-3	3.3793
M-901	3.3793
SELF-PROP.	3.3793
A-6	3.1034
S-3	2.8158
ATT. SUBS	2.8050
M-48	2.6284
TOWED ART.	2.5345
MORTERS	2.5188
GLCMS	2.1903
SH-60B	2.0390
FRIGATES	1.6830
PERSHING	1.4081
MLRS	1.4081
SH-2	1.2137
DSTROYERS	1.0098
RADIO RLAY	0.5023
SH-3	0.4855
M-113	0.4694
ART. ACRFT	0.2768
RCLES LNCH	0.0469
M-551	0.0266

Scenario 31.

BASELINE: REDUCE IMPORTANCE OF COBALT TO JET ENGINES

COBALT

NORMALIZED VALUES	
M-1	10.0000
M-60	9.0000
M-901	8.0000
F-111	7.1563
M-2/M-3	7.0000
F-16	6.2107
F-4	6.1273
M-48	5.6000
MORTERS	5.4444
SELF-PROP.	5.3333
GLCMS	4.4444
A-10	4.0230
TOWED ART.	4.0000
F-18	3.9757
COBRA	3.5760
ATT. SUBS	3.5572
F-15	3.1806
MLRS	3.0000
A-7	2.8625
PERSHING	2.6667
F-14	2.3854
A-6	2.1469
FRIGATES	2.1343
S-3	1.9209
SH-60B	1.4940
DSTROYERS	1.2806
INFANTRY	1.1111
SH-2	0.9604
RADIO RLAY	0.8794
M-113	0.7778
ART. ACRFT	0.5364
SH-3	0.3842
RCLES LNCH	0.2333
M-551	0.0333

ALL COMMODITIES

NORMALIZED VALUES	
F-111	10.0000
F-16	8.6787
F-4	7.9717
F-18	5.9387
A-10	5.6216
INFANTRY	5.1398
F-15	4.4444
M-1	4.3367
M-60	4.3367
A-7	4.0000
COBRA	3.9632
F-14	3.5632
SELF-PROP.	3.4694
M-2/M-3	3.4694
M-901	3.4694
A-6	3.1034
M-48	2.6984
S-3	2.6842
ATT. SUBS	2.6739
TOWED ART.	2.6020
MORTERS	2.5860
GLCMS	2.2487
SH-60B	1.9437
FRIGATES	1.6043
PERSHING	1.4456
MLRS	1.4456
SH-2	1.1570
DSTROYERS	0.9626
RADIO RLAY	0.5085
M-113	0.4819
SH-3	0.4628
ART. ACRFT	0.2843
RCLES LNCH	0.0482
M-551	0.0273

only four of the thirty force elements. Consequently, the values in Figures 19 and 20 are indicative of the sensitivity of the methodology only and are not to be considered as absolute relationships. The follow-on effort will address the subelements of all force elements as well as the remaining commodities in the strategic and critical material stockpile.

CONCLUSIONS

The demonstration of the Decision Science methodology has conclusively shown the capability to relate commodities, sources, stockpile requirements, military assets and the external environment (military, political, and socioeconomic in a dynamic, interactive evaluation of strategies relative to the strategic and critical material stockpile. With this adjunct to existing FEMA models, FEMA will have the analytic tools necessary to simulate the various strategies and thus achieve a better outcome of the vital decision process as it relates to the assurance of national security.

Further, the definition of the Joint US/USSR Purpose enables for the first time a *quantitative evaluation of the* interactions of the superpowers and how these affect our stockpile strategies. This is a key asset for use in stockpile strategy formulations, considering the moves and countermoves of the major protagonists in the arena of critical materials.

The structure and methodology have been completed to satisfactorily demonstrate an ability to fulfill each of the six contract tasks.

RECOMMENDATIONS

Enlarge the study to provide FEMA decision makers with an analytic tool for simulation of strategic and critical material acquisition strategies.

Specifically, the Joint US/USSR Purpose should be definitized to a finer detail and the joint payoff functions defined. Further, to be even more meaningful, this should be designed to include additional players as they affect the decision process.

The methodology should be expanded to encompass all the critical and strategic materials in the stockpile in relationship to all the subelements of the force elements in the data base. This should be time sensitive, and consider expert input in the weighting process.

Application to the other two defense tiers should be determined, once the military aspects are well defined.

The dynamic model and interactive computer program should be completed to include the above and be made a deliverable.

APPENDIX A

FORCE ELEMENTS

APPENDIX A

LAND CONTROL FORCE ELEMENTS

1. AIR INTERDICTION AIRCRAFT FORCES

   Aircraft used to prevent or impede enemy use of an area or route.

2. AMPHIBIOUS ASSAULT FORCES

   Naval and ground forces trained, organized and equipped to assault a hostile shore from the sea.

3. ARMY GROUND COMBAT FORCES

   Army armored, mechanized and infantry forces.

4. CHEMICAL/BIOLOGICAL WARFARE FORCES

   The use of asphyxiating, poisonous, and corrosive gases, flames, aerosols, liquid sprays, living microorganisms and toxic agents derived from dead microorganisms so as to produce lethal or nonlethal casualties among humans and animals and/or damage to plants and material; defense against such actions.

5. CIVIL DEFENSE FORCES

   Passive measures designed to minimize the effects of enemy action on all aspects of civil life, particularly to protect the population and production base. Includes emergency steps to repair or restore vital utilities and facilities.

6. CLOSE AIR SUPPORT AIRCRAFT FORCES

   Aircraft used for air strikes against targets near enough to ground combat units that detailed coordination between participating air and ground elements is required.

7. INTERCONTINENTAL BALLISTIC MISSILE FORCES

Ballistic missiles with ranges of 3,000 to 8,000 nautical miles.

8. RAPID DEPLOYMENT FORCES

The reservoir of forces suitable for use in a wide range of non-NATO contingencies.

9. SPACE-BASED WEAPON FORCES

Space-based weapon systems, the purpose of which is to damage or destroy hostile land-based forces.

10. STRATEGIC BOMBER FORCES

Multi-engined aircraft with intercontinental range, designed specifically to engage targets whose destruction would reduce an enemy's capacity and/or will to wage war. Includes short- and long-range ground attack weapon systems, such as the ALCM.

11. SUBMARINE LAUNCHED BALLISTIC MISSILE FORCES

Ballistic missiles transported by and launched from a ship. May be short-, medium-, intermediate-, or long-range.

12. THEATER NUCLEAR MISSILE FORCES

Nuclear warhead equipped missiles designed for deterrent, offensive, and defensive purposes that contribute to the accomplishment of located military missions.

13. SPECIAL OPERATIONS FORCES

Special operations, which are undertaken in enemy controlled or politically sensitive territory, cover a broad spectrum of actions. Two facets of special operations are unconventional warfare and foreign internal defense.

SEA CONTROL FORCE ELEMENTS

14. ANTI-SUBMARINE WARFARE FORCES (ASW)(LAND BASED)

Land-based forces whose purpose is to reduce or nullify the effectiveness of hostile submarines. This involves detection, localization, tracking and destroying hostile submarines.

15. MARITIME PATROL AND ASW FORCES (SEA BASED)

Ship-based forces whose purpose it is to reduce or nullify the effectiveness of hostile submarines. This involves operation to detect, locate, track, and destroy submarines used for strategic nuclear and conventional purposes.

16. ATTACK SUBMARINE FORCES

Submarines designed primarily to destroy enemy merchant shipping and naval vessels, including other submarines.

17. CARRIER BATTLE GROUP FORCES

An aircraft carrier, its embarked air wing and supporting ships, whose primary purpose is to project offensive striking power against targets ashore and afloat.

18. MINE WARFARE FORCES

Preventing the passage of ships by mining harbors, waterways and open ocean areas.

19. SURFACE COMBATANT FORCES

Surface warships (cruisers, destroyers and frigates) armed for independent offensive operations

against surface ships and land targets. They also act as escorts to protect aircraft carriers, merchantmen, and other ships against surface or air attack. Own aircraft-handling capability is restricted to helicopters.

30. SPACE-BASED WEAPON FORCES

Space-based weapons systems whose purpose is to damage or destroy sea-based forces.

AIR CONTROL FORCE ELEMENTS

20. AIR DEFENSE FORCES (LAND BASED)

Land-based missile and AAA equipped forces whose purpose it is to intercept and destroy hostile aircraft. Equipment includes weapons, target acquisition, tracking and guidance and control systems.

21. AIR DEFENSE FORCES (SHIP-BASED)

Shipboard surface-to-air missile and AAA systems whose purpose it is to intercept and destroy hostile aircraft. Equipment includes weapons and target acquisition, tracking and guidance and control systems.

22. AIR SUPERIORITY AIRCRAFT FORCES (LAND-BASED)

Land-based fighter aircraft whose purpose it is to dominate in the air to a degree that permits friendly land, sea, and air forces to operate on, over or near specific continental land areas without prohibitive interference by enemy air forces.

23. AIR SUPERIORITY AIRCRAFT FORCES (SHIP-BASED)

Sea-based fighter aircraft whose purpose it is to deominate in the air to a degree that permits friendly land, sea, and air forces to operate on, over or near specific ocean areas without prohibitive interference by enemy air forces.

24. INTERCEPTOR AIRCRAFT FORCES

Air defense aircraft designed to identify and/or destroy hostile air-breathing weapon systems, such as bombers and cruise missiles.

25. SPACE-BASED INTERCEPTOR FORCES

Space-based systems designed to destroy hostile airbreathing weapon systems, such as bombers and cruise missiles.

SPACE CONTROL FORCE ELEMENTS

26. ANTIBALLISTIC MISSILE DEFENSE FORCES (LAND-BASED)

Land-based systems whose purpose it is to intercept and destroy hostile ballistic missiles or their payloads in flight at short-, medium-, or long-range inside or outside the atmosphere, or otherwise neutralize them. Equipment includes weapons (may be laser, maser, nuclear, or conventional); target acquisition, tracking and guidance radars; and ancillary installations.

27. ANTIBALLISTIC MISSILE DEFENSE FORCES (SPACE-BASED)

Space-based systems whose purpose it is to intercept and destroy or neutralize hostile ballistic missiles in flight, normally outside the atmosphere.

28. ANTISATELLITE FORCES (LAND-BASED)

Land-based systems whose purpose it is to destroy hostile satellites, or otherwise neutralize them. Equipment includes weapon, target acquisition, tracking and guidance radars, and ancillary installations.

29. ANTISATELLITE FORCES (SPACE-BASED)

Space-based systems whose purpose it is to destroy hostile satellites, or otherwise neutralize them.

APPENDIX B

CALCULATION OF FORCE ELEMENT/COMMODITY IMPORTANCES

APPENDIX B

CALCULATION OF FORCE ELEMENT/COMMODITY IMPORTANCES

The four selected Force Elements include land, sea and air systems. Space, as a control media, was not a part of this analysis. Once the Force Element is selected, it is decomposed to its subelements[1] which contribute to its associated "end." It should be noted here that these include only those elements which deliver ordnance, or essentially function in direct support of weapon delivery, such as combat zone artillery spotter aircraft. Ordnance is considered part of the weapon system subelement. For this demonstration analysis, elements such as ground-based radar have not been in-included, although they should be assessed and incorporated if they could impact the stockpile. Moreover, it was agreed that only four representative force elements would be considered in this phase of the demonstration to ensure an adequate representation within time and fiscal constraints. Once the force element subelements are determined,[1] the importance of the subelement to the overall military importance of the force element is assessed in the continuum from zero to ten considering the parameters in the following valuated state space expression:

---

(1) See Bibliography for Source Documents.

10 Critical

8 Very Important

5 Average Contribution

3 Complements or Supplements other Elements

0 No Contribution

The second step is to determine the importance of the commodity to the subelement. Again, this is assessed on a zero-to-ten scale suggested by the following levels:

10 Lack of Material Precludes Construction and/or Efficient Operation.

8 Reduced Amount of Material Results in Performance that is Significantly Impaired.

6 Reduced Amount of Material Results in Some Performance Degradation.

3 Reduced Amount of Material Results in Very Little Performance Degradation.

0 Reduced Amount of Material has No Noticeable Impact on Performance.

This assessment is repeated for each of the commodities being considered, for each of the subelements.

The third step is to assess each of the subelements in terms of its acquisition and/or support status. As before, this is assessed within the zero-to-ten scale suggested by the following:

10 Acquisition will Continue through the Stockpile Conflict Scenario.

9 Major Commodity Users (e.g., Engines) will be Replaced through the Conflict.

6 Major Commodity Users have Moderate Replacement Rates.

3 Major Commodity Users have Low Replacement Rates.

0 Replacement Needs not a Factor.

Weights are then assigned to each of the subelements and each subelement's contribution to the Force Element importance is its own weight divided by the summation of all weights. The importance of the specific commodities and the acquisition/ support status are assigned a value between zero and ten which is expressed as a decimal number between zero and one in calculating importances.

Specific value assignments are as follows

FORCE ELEMENT: CLOSE AIR SUPPORT (3.132)

COMMODITY / SUBELEMENT / WEIGHT		COBALT	NICKEL	PRYETHRUM	TIN	FLUORSPAR ACID	ACQUISITION SUPPORT	
A-10	10	8	8	0	8	10	9	
COBRA	8	6	6	0	8	6	10	
F-4	1	8	6	0	8	10	9	
F-16	5	8	8	0	8	10	10	
ARTILLERY AIRCRAFT	4	3	2	0	3	3	3	
RADIO RELAY	3	3	3	0	3	3	3	
	31							

FORCE ELEMENT: AIR INTERDICTION (8.266)

COMMODITY / SUBELEMENT WEIGHT		COBALT	NICKEL	PRYETHRUM	TIN	FLUORSPAR ACID	ACQUISITION SUPPORT	
F-111	10	8	8	0	8	10	9	
A-6	3	8	8	0	9	10	9	
F-15	4	8	8	0	8	10	10	
A-7	6	8	8	0	8	10	6	
F-4	8	8	6	0	8	10	9	
F-16	5	8	8	0	8	10	10	
F-14	3	8	9	0	9	10	10	
F-18	5	8	9	0	9	10	10	
RADIO RELAY	2	3	3	0	3	3	3	
	46							

FORCE ELEMENT: ASW (SEA-BASED) (2.315)

COMMODITY / SUBELEMENT / WEIGHT		COBALT	NICKEL	PRYETHRUM	TIN	FLUORSPAR ACID	ACQUISITION SUPPORT ***	
SH-3	6	7	8	0	6	8	3	
SH-2	5	7	8	0	6	8	9	
SH-60B	7	7	8	0	6	10	10	
S-3	10	8	8	0	8	10	9	
ATT. SUBS	10	5	9	3	3	6	10	
FRIGATES	6	5	9	0	5	7	10	
DESTROYERS	4	5	9	0	5	7	9	
	48							

* The above systems are considered as an entity with the
* ordnance. Consequently, the acquisition values include
* continuing supplies of antitank weapons, torpedoes, etc.

FORCE ELEMENT: ARMY GROUND (7.382)

COMMODITY / SUBELEMENT / WEIGHT		COBALT	NICKEL	PRYETHRUM	TIN	FLUORSPAR ACID	ACQUISITION SUPPORT ***	
M-48	8	9	10	7	1	3	7	
M-60	9	9	10	7	1	3	10	
M-1	10	9	10	0	5	3	10	
M-551	1	3	10	0	1	3	1	
M-901	9	8	7	0	1	8	10	
M-2/M-3	9	7	8	0	1	8	10	
M-113	5	7	7	7	1	8	2	
MLRS	5	6	6	0	3	5	9	
TOWED ARTILLERY	6	6	8	7	1	5	10	
SELF-PROPELLED	8	6	8	7	1	5	10	
PERSHING	3	8	8	0	7	7	10	
GLCMS	5	8	6	0	7	7	10	
INFANTRY	10	1	5	10	8	8	10	
MORTERS	7	7	3	7	1	5	10	
RECOILESS LAUNCHERS	3	7	1	0	1	1	1	
	98							

* The above systems are considered as an entity with the
* ordnance. Consequently, the acquisition values include
* continuing supplies of antitank weapons, torpedoes, etc.

The use of the refined technique described above opens many new avenues for considering the strategic and critical stockpile. First, as discussed earlier, a more detailed assessment of the importance of a commodity can be determined which can then be evaluated with the method developed in the earlier reporting periods. Second, the demands on the stockpile can be determined by the subelements of each of the force elements, expressed in terms of the specific commodities or combination of commodities. And, finally, the importance of the weapon systems considered over all commodities and the force elements to which they contribute can be determined and a ranking developed which will assist in the prioritization in light of limited stockpiles and our national purpose.

The next task is to calculate the commodity importances to provide a more refined view than considered in the earlier analyses and to determine weapon importances to assist in stockpile access prioritization. Since the approach is identical for all the Force Elements considered, only Close Air Support will be portrayed in detail.

Values in their respective cells are described as follows using the A-10 as an example: $\frac{10}{30}$ = Importance of the A-10 to the CAS Mission Divided by the Sum of the Importance of all the Subelements; .8 = Importance of a Specific Commodity to the Subelement, expressed as a decimal; .9 = the Acquisition/Support Status of the Subelement, expressed as a decimal.

CLOSE AIR SUPPORT (3.132)

WEAPON SYSTEM / COMMODITY	A-10	COBRA	F-4	F-16	ARTILLERY AIRCRAFT	RADIO RELAY	Σ COMMODIT
COBALT	$\frac{10}{31}$ X .8 X .9	$\frac{8}{31}$ X .6 X 1.0	$\frac{1}{31}$ X .8 X .9	$\frac{5}{31}$ X .8 X 1.0	$\frac{4}{31}$ X .3 X .3	$\frac{3}{31}$ X .3 X .3	.5597
NICKEL	$\frac{10}{31}$ X .8 X .9	$\frac{8}{31}$ X .6 X 1.0	$\frac{1}{31}$ X .6 X .9	$\frac{5}{31}$ X .8 X 1.0	$\frac{4}{31}$ X .2 X .3	$\frac{3}{31}$ X .3 X .3	.5500
PYRETHRUM	$\frac{10}{31}$ X 0	$\frac{8}{31}$ X 0	$\frac{1}{31}$ X 0	$\frac{5}{31}$ X 0	$\frac{4}{31}$ X 0	$\frac{3}{31}$ X 0	0
TIN	$\frac{10}{31}$ X .8 X .9	$\frac{8}{31}$ X .8 X 1.0	$\frac{1}{31}$ X .8 X .9	$\frac{5}{31}$ X .8 X 1.0	$\frac{4}{31}$ X .3 X .3	$\frac{3}{31}$ X .3 X .3	.611
FLUORSPAR ACID	$\frac{10}{31}$ X 1.0 X .9	$\frac{8}{31}$ X .6 X 1.0	$\frac{1}{31}$ X 1.0 X .9	$\frac{5}{31}$ X 1.0 X 1.0	$\frac{4}{31}$ X .3 X .3	$\frac{3}{31}$ X .3 X .3	.655
Σ WEAPON SYSTEM	.9871	.6710	.0929	.5484	.0426	.0348	

AIR INTERDICTION (8.266) •••

WEAPON SYSTEM / COMMODITY	F-111	A-6	F-15	A-7	F-4	F-16	F-14	F-18	RADIO RELAY	Σ COMMODITY
COBALT										.6909
NICKEL										.6707
PYRETHRUM										0
TIN										.7141
FLUORSPAR ACID										.8626
Σ WEAPON SYSTEM	.6652	.2054	.2957	.2661	.5000	.3696	.2348	.3913	.0157	

••• SEE "CLOSE AIR SUPPORT" FOR INTERNAL ARITHMETIC METHODOLOGY.

ASW (SEA-BASED) (2.315) ***

WEAPON SYSTEM / COMMODITY	SH-3	SH-2	SH-60	S-3	ATT. SUBS	FRIGAGES	DESTROYERS	Σ COMMODITY		
COBALT								.5481		
NICKEL								.7392		
PYRETHRUM								.0625		
TIN								.4788		
FLUORSPAR ACID								.7033		
Σ WEAPON SYSTEM	.1088	.2719	.4521	.6375	.5417	.3250	.1950			

*** SEE "CLOSE AIR SUPPORT" FOR INTERNAL ARITHMETIC METHODOLOGY.

ARMY GROUND (7.382) •••

WEAPON SYSTEM / COMMODITY	M-48	M-60	M-1	M-551	M-901	M-2/M-3	M-113	MLRS	TOWED ART.	SELF-PROPELLED	PERSHING	GLCM	INFANTRY	MORTERS	RECOILESS LAUNCHING	Σ COMMODITY
COBALT																.6120
NICKEL																.6666
PYRETHRUM																.3635
TIN																.2597
FLUORSPAR ACID																.4497
Σ WEAPON SYSTEM	.1714	.2755	.2755	.0017	.2204	.2204	.0306	.0918	.1653	.2204	.0918	.1428	.3265	.1643	.0031	

••• SEE "CLOSE AIR SUPPORT" FOR INTERNAL ARITHMETIC METHODOLOGY.

The commodity comparative importances can be calculated from the Table and the force element importance as follows:

Σ Cobalt	=	CAS	.5597	X	3.132
		AIR INT'N	.6909	X	8.266
		ASW (SEA)	.5481	X	2.315
		ARMY GRND	.6120	X	7.382
					13.25
Σ Nickel	=	CAS	.5500	X	3.132
		AIR INT'N	.6770	X	8.266
		ASW(SEA)	.7392	X	2.315
		ARMY GRND	.6666	X	7.382
					13.95
Σ Pyrethrum	=	CAS	.0000	X	3.132
		AIR INT'N	.0000	X	8.266
		ASW (SEA)	.0625	X	2.315
		ARMY GRND	.3635	X	7.382
					2.83
Σ Tin	=	CAS	.6113	X	3.132
		AIR INT'N	.7141	X	8.266
		ASW (SEA)	.4788	X	2.315
		ARMY GRND	.2597	X	7.382
					10.84
Σ Fluor. Acid	=	CAS	.6558	X	3.132
		AIR INT'N	.8626	X	8.266
		ASW (SEA)	.7033	X	2.315
		ARMY GRND	.4497	X	7.382
					14.13

The normalized values (four force elements only) are as follows:

Fluorspar Acid	=	10.00
Nickel	=	9.87
Cobalt	=	9.38
Tin	=	7.67
Pyrethrum	=	2.00

Next, subelement importance by commodity can be calculated. As an example, consider the commodity cobalt and the subelements S-3, F-111, F-16 and M-1. The calculation incorporates the importance of the subelement to the Force Element(s) it supports, the importance of the commodity, the acquisition/support status and the Force Element importance, in that order. Note that a subelement may contribute to more than one Force Element.

Cobalt

S-3	ASW	=	10/48	X	.8	X	.9	X	2.315	=	.3473
F-111	AIR INT'N	=	10/46	X	.8	X	.9	X	8.266	=	1.2938
F-16	CAS	=	5/31	X	.8	X	1.0	X	3.132		
	AIR INT'N	+	5/46	X	.8	X	1.0	X	8.266	=	1.1229
M-1	ARMY GRND	=	10/98	X	.9	X	1.0	X	7.382	=	.6779

The normalized values are shown below:

F-111 = 10.00

F-16 = 9.94

M-1 = 6.00

S-3 = 3.08

Thus, prioritized access to a specific commodity can be determined, in the context of achievement of national purpose, as well as the commodity importance and acquisition/support requirements.

As a final example, the subelements can be prioritized over all missions and commodities. The values used in the calculations are obtained from tables of this appendix.

All Commodities

S-3	ASW	=	.6375	X	2.315	=	1.4758
F-111	AIR INT'N	=	.6652	X	8.266	=	5.4985
F-16	CAS	=	.5484	X	3.132		
	AIR INT'L	+	.3696	X	8.266	=	4.7727
M-1	ARMY GRND	=	.2755	X	7.382	=	2.0337

The normalized values are shown below:

F-111 = 10.00

F-16 = 8.68

M-1 = 3.70

S-3 = 2.68

Note that there is a shift in relative importances as the various factors/commodities are taken into account.

APPENDIX C

SOURCE/MEDIA/REGION RELATIONSHIPS

APPENDIX C

SOURCE/MEDIA/REGION RELATIONSHIPS

Within the computer program, for computation, each media andassociated regions are uniquely identified and numerically designated as shown in this appendix. Each of the sources is also identified by a numerical designator and the applicable media and regions defined.

LIST OF SOURCES BY NUMBER

1 FINLAND
2 MOROCCO
3 BOTSWANNA
4 SOUTH AFRICA
5 ZAIRE
6 ZAMBIA
7 PHILIPPINES
8 AUSTRALIA
9 NEW CALEDONIA
10 CANADA
11 U S
12 ITALY
13 SPAIN
14 EAST AFRICA
15 THAILAND
16 MEXICO
17 GREECE
18 NETHERLANDS
19 FRG
20 YUGOSLAVIA
21 USSR
22 DOM. REPUB.
23 GUATAMALA
24 INDONESIA
25 UK
26 KENYA
27 RWANDA
28 TANZANIA
29 BOLIVIA
30 BRAZIL
31 PRC
32 MALAYSIA

LIST OF COMMODITIES BY NUMBER

1 COBALT
2 TIN
3 NICKEL
4 FLUORSPAR ACID
5 PYRETHRUM

REGIONS BY MEDIA

MEDIA 1 LAND
1 NORTH AMERICA
2 EUROPE
3 REPUBLIC OF KOREA/JAPAN
4 S. E. ASIA/AUST/NEW ZEALAND
5 MIDDLE EAST
6 THIRD WORLD
7 SOVIET UNION
8 WARSAW PACT
9 SOUTH AMERICA
10 CENTRAL AMERICA

MEDIA 2 AIR
1 N. AMERICA/W. ATLAN/CARIB.
2 EUROPE/MEDITERRANEAN
3 NORTH ATLANTIC
4 SOVIET UNION
5 N. E. ASIA/(KOREA/JAPAN)
6 S. E. ASIA/AUST/NEW ZEALAND
7 THIRD WORLD
8 WARSAW PACT
9 MIDDLE EAST
10 SOUTH AMERICA
11 CENTRAL AMERICA

MEDIA 3 SEA
1 WEST ATLANTIC/CARIBBEAN
2 N. E. PACIFIC(HAWAII/ALASKA)
3 N. ATLANTIC/MEDITERRANEAN
4 PERSIAN GULF/INDIAN OCEAN
5 N. W. PACIFIC(KOREA/JAPAN)
6 S. E. ASIA/AUST/NEW ZEALAND
7 SOUTH ATLANTIC

MEDIA 4 SPACE
1 LOW-ALTITUDE
2 MID-ALTITUDE
3 SYNCHRONOUS
4 SUPER SYNCHRONOUS

LEGEND
SOURCE DEFINITIONS BY MEDIA AND REGION

SOURCE	MEDIA	REGION
1 FINLAND	LAND	EUROPE
	AIR	NORTH ATLANTIC
	SEA	N. ATLANTIC/MEDITERRANEAN
2 MOROCCO	LAND	THIRD WORLD
	AIR	NORTH ATLANTIC
		EUROPE/MEDITERRANEAN
	SEA	N. ATLANTIC/MEDITERRANEAN
3 BOTSWANNA	LAND	THIRD WORLD
	AIR	THIRD WORLD
	SEA	PERSIAN GULF/INDIAN OCEAN
4 SOUTH AFRICA	LAND	THIRD WORLD
	AIR	THIRD WORLD
	SEA	PERSIAN GULF/INDIAN OCEAN
		SOUTH ATLANTIC
5 ZAIRE	LAND	THIRD WORLD
	AIR	THIRD WORLD
	SEA	SOUTH ATLANTIC
6 ZAMBIA	LAND	THIRD WORLD
	AIR	THIRD WORLD
	SEA	SOUTH ATLANTIC
7 PHILIPPINES	LAND	S. E. ASIA/AUST/NEW ZEALAND
	AIR	S. E. ASIA/AUST/NEW ZEALAND
	SEA	S. E. ASIA/AUST/NEW ZEALAND
8 AUSTRALIA	LAND	S. E. ASIA/AUST/NEW ZEALAND
	AIR	S. E. ASIA/AUST/NEW ZEALAND
	SEA	S. E. ASIA/AUST/NEW ZEALAND
9 NEW CALEDONIA	LAND	S. E. ASIA/AUST/NEW ZEALAND
	AIR	S. E. ASIA/AUST/NEW ZEALAND
	SEA	S. E. ASIA/AUST/NEW ZEALAND
10 CANADA	LAND	NORTH AMERICA
	AIR	N. AMERICA/W. ATLAN/CARIB.
		NORTH ATLANTIC
	SEA	N. ATLANTIC/MEDITERRANEAN
		N. E. PACIFIC(HAWAII/ALASKA)
11 U S	LAND	NORTH AMERICA
	AIR	N. AMERICA/W. ATLAN/CARIB.
	SEA	WEST ATLANTIC/CARIBBEAN
		N. E. PACIFIC(HAWAII/ALASKA)
12 ITALY	LAND	EUROPE
	AIR	EUROPE/MEDITERRANEAN
	SEA	N. ATLANTIC/MEDITERRANEAN
13 SPAIN	LAND	EUROPE
	AIR	EUROPE/MEDITERRANEAN
	SEA	N. ATLANTIC/MEDITERRANEAN
14 EAST AFRICA	LAND	THIRD WORLD
	AIR	THIRD WORLD
	SEA	PERSIAN GULF/INDIAN OCEAN
15 THAILAND	LAND	S. E. ASIA/AUST/NEW ZEALAND
	AIR	S. E. ASIA/AUST/NEW ZEALAND
	SEA	S. E. ASIA/AUST/NEW ZEALAND
16 MEXICO	LAND	NORTH AMERICA
	AIR	N. AMERICA/W. ATLAN/CARIB.
	SEA	WEST ATLANTIC/CARIBBEAN
		N. E. PACIFIC(HAWAII/ALASKA)

17 GREECE	LAND	EUROPE
	AIR	EUROPE/MEDITERRANEAN
	SEA	N. ATLANTIC/MEDITERRANEAN
18 NETHERLANDS	LAND	EUROPE
	AIR	EUROPE/MEDITERRANEAN
	SEA	N. ATLANTIC/MEDITERRANEAN
19 FRG	LAND	EUROPE
	AIR	EUROPE/MEDITERRANEAN
	SEA	N. ATLANTIC/MEDITERRANEAN
20 YUGOSLAVIA	LAND	EUROPE
	AIR	EUROPE/MEDITERRANEAN
	SEA	N. ATLANTIC/MEDITERRANEAN
21 USSR	LAND	SOVIET UNION
	AIR	SOVIET UNION
	SEA	N. ATLANTIC/MEDITERRANEAN
22 DOM. REPUB.	LAND	CENTRAL AMERICA
	AIR	CENTRAL AMERICA
	SEA	WEST ATLANTIC/CARIBBEAN
23 GUATAMALA	LAND	CENTRAL AMERICA
	AIR	CENTRAL AMERICA
	SEA	N. E. PACIFIC(HAWAII/ALASKA)
24 INDONESIA	LAND	S. E. ASIA/AUST/NEW ZEALAND
	AIR	S. E. ASIA/AUST/NEW ZEALAND
	SEA	S. E. ASIA/AUST/NEW ZEALAND
25 UK	LAND	EUROPE
	AIR	EUROPE/MEDITERRANEAN
	SEA	N. ATLANTIC/MEDITERRANEAN
26 KENYA	LAND	THIRD WORLD
	AIR	THIRD WORLD
	SEA	PERSIAN GULF/INDIAN OCEAN
27 RWANDA	LAND	THIRD WORLD
	AIR	THIRD WORLD
	SEA	PERSIAN GULF/INDIAN OCEAN
28 TANZANIA	LAND	THIRD WORLD
	AIR	THIRD WORLD
	SEA	PERSIAN GULF/INDIAN OCEAN
29 BOLIVIA	LAND	SOUTH AMERICA
	AIR	SOUTH AMERICA
	SEA	N. E. PACIFIC(HAWAII/ALASKA)
30 BRAZIL	LAND	SOUTH AMERICA
	AIR	SOUTH AMERICA
	SEA	SOUTH ATLANTIC
31 PRC	LAND	S. E. ASIA/AUST/NEW ZEALAND REPUBLIC OF KOREA/JAPAN
	AIR	S. E. ASIA/AUST/NEW ZEALAND N. E. ASIA/(KOREA/JAPAN)
	SEA	PERSIAN GULF/INDIAN OCEAN N. W. PACIFIC(KOREA/JAPAN)
32 MALAYSIA	LAND	S. E. ASIA/AUST/NEW ZEALAND
	AIR	S. E. ASIA/AUST/NEW ZEALAND
	SEA	S. E. ASIA/AUST/NEW ZEALAND

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